THE INSTITUTION OF PRODUCTION ENGINEERS JOURNAL

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PRODUCTION ENGINEERS JOURNAL

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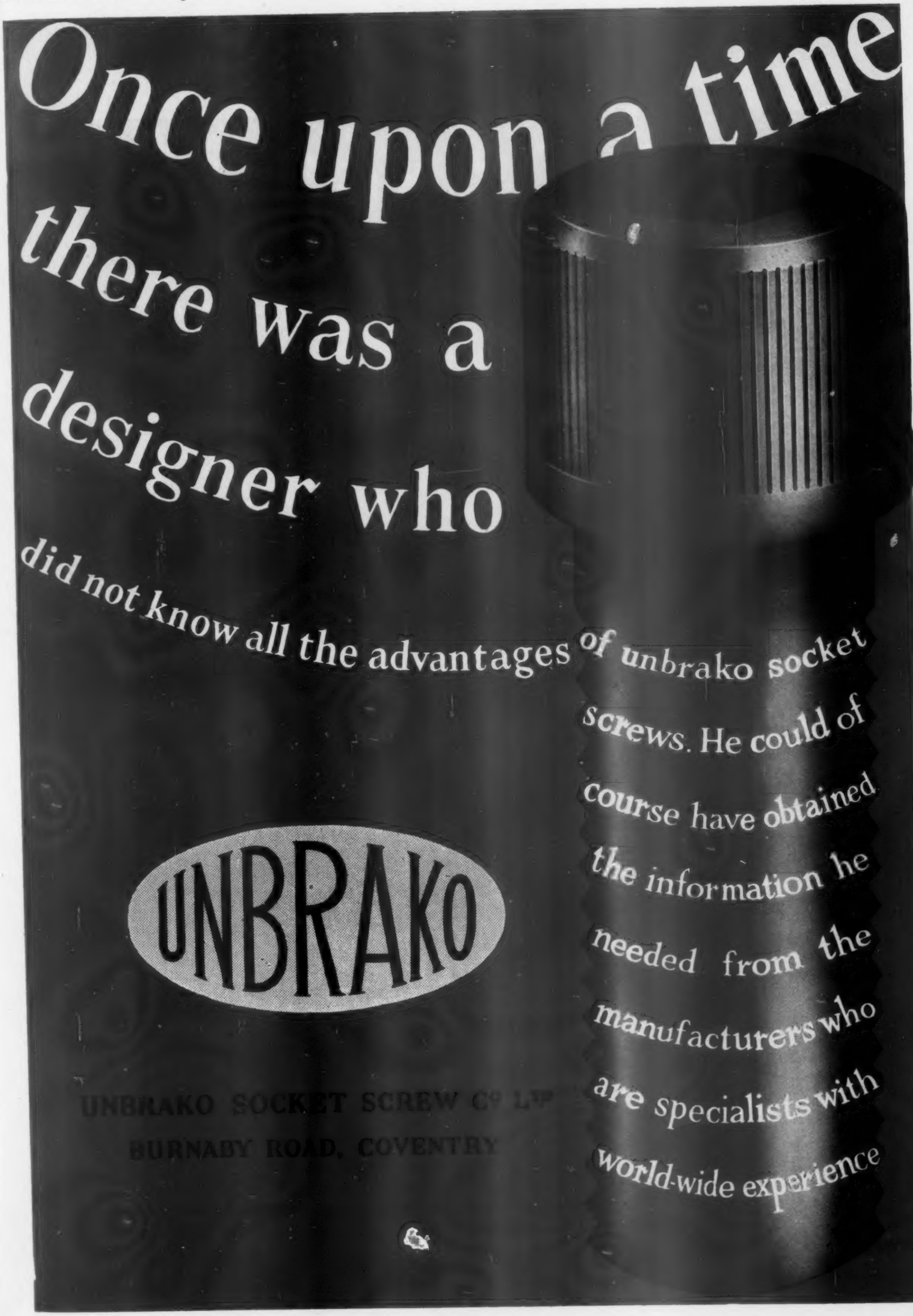
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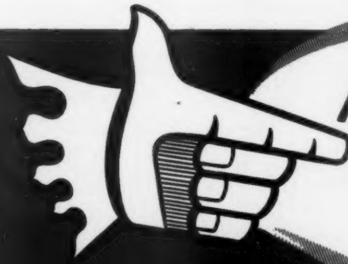

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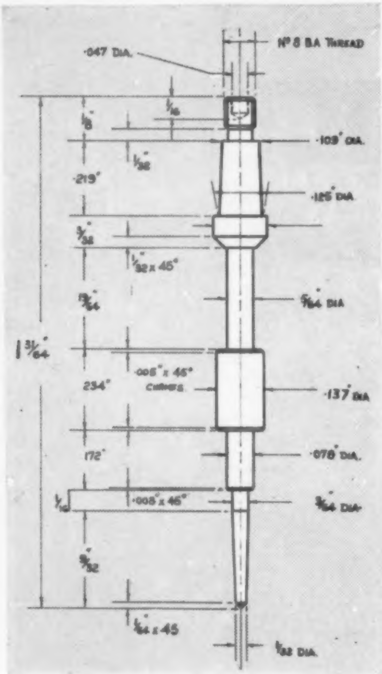

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The Institution of Production Engineers Journal

VOL. 32. NO. 2 FEBRUARY, 1953

How Few Production Engineers ?

by WALTER C. PUCKEY, M.I.Prod.E., F.I.I.A.,

Deputy Controller of Supplies (Aircraft Production), Ministry of Supply.

The Institution has invited several distinguished personalities to comment on "an expansionist policy for production." In the first contribution to this series, Mr. Puckey emphasises the vital need for more Production Engineers and for careful selection and training of those who will be expected to operate such a policy.

I AM told that this series of articles should deal with an 'expansionist policy for production' and, as this is an age where the value of men has transcended the value of machines, when we speak of production we really speak of the men who practice it. No 'expansionist policy for production' is therefore possible without continuous attention being given to the selection, training and enthusing of those who are expected to plan and achieve that policy.

What is meant by this phrase ? Does it mean that we must plan for a continuous expansion in the physical volume of output of all products in order to raise our standard of living ? That production techniques must be more intensively introduced and applied over a much wider range of national activities ? That Commonwealth collaboration implies, in future, a much greater industrial expansion around the rim of the Commonwealth, with proportionately greater strength at the British 'hub' ?

It seems, to me, all these and more. It certainly means that every political experiment—nationalisation, denationalisation, the European Coal and Steel Community (to quote our President)—sets new production problems, made relatively more rather than less difficult by their scope and their international ramifications.

It means, also, the problem of catering for a greatly increased world population. It is estimated that the U.S.A. alone will have increased its total population by 42 million when 1975 is reached, and only 20 million are likely to be added to the *working force*. What an expansionist policy for production to be applied there !

I think, also, of the problem of world competition which will affect so deeply an exporting nation like Britain. We must always be comparing ourselves, not against an abstract standard but against what others are doing.

We must also increase production and productivity in a period when real capital is likely to be all too scarce. Mr. Chambers has once again done a service in bringing this to our attention[1] and today's capital formation conditions will make it very difficult for the Production Engineer—indeed, every executive—to carry out an expansionist policy.

But whichever way you interpret the phrase, there are plenty of tasks ahead for the production executive. To my mind the real task is to provide the men able to perform these many tasks and, unfortunately, this is not only the most pressing but the longest job of all. I have often wondered why there are not more Board Meetings where *men* are discussed rather than things. All too often I see senior men with no adequate deputies; too often I find less than an essential recognition of the

1. January 1953 Journal, pages 2/3.

necessity to put more into the junior end than is being taken out of the senior end. To be fair, one must acknowledge the great increase in training schemes of all types in the last decade; they are bound to have great effect in the years to come but—they are not enough.

Unfortunately, Production Engineering is still relatively new as a recognised speciality, and even with our spectacular rate of growth the total number of qualified men produced each year is very small, in relation to real demand. One difficulty is to estimate the number of trained Production Engineers that the nation really should have, and the results of any such calculation are bound to be empirical.

The Institution has made a bold attempt to estimate the future, and its conclusions provide both a shock and an inspiration. Although the calculations are based on incomplete evidence, they are of great value in taking us nearer to the truth. The growth of Higher National Certificate Schemes is taken as a basis for estimating numerical growth, and it is heartening to see the steep rate of climb in students qualifying for the H.N.C. in Production Engineering. From 19 in 1942, it rose to about 400 last year. Compare this figure, however, with over 5000 qualifying for H.N.C.'s over the whole range of industrial training activities and you will realise how small is the present output of trained Production Engineers. Is it not fair to assume that as production is the essential end to every industrial activity, there should be at least as many Production Engineers produced each year as the total of all other industrial graduates ? However, we are nowhere near as optimistic as this ; we assume that there should be one Production Engineer employed to every so many workers in industry—in engineering we take the ratio of one Production Engineer to every 300 workers Assuming a wastage of Production Engineers through retirement (if ever) and other causes, our view is that the minimum number of new Production Engineers required by Britain for her own use, each year, is 1,100 and at our current rate of H.N.C. growth, this yearly output will not be achieved before 1962—nine years ahead !

We can make other calculations. Taking a recent F.B.I. Report[2] as a basis, and assuming that there should be at least one qualified Production Engineer to every qualified Research Engineer in industry, we should have at least 37,000 Production Engineers today. At our current rate of provision and wastage, this will take about 50 years to achieve!

Look at it yet another way. There are at least 45,000 manufacturing units in the United Kingdom. Assume that each requires at least *one* trained Production Engineer, whose effective life is, say, 30 years. We thus want at least 1,500 new Production Engineers each year to replace the existing trained force. This rate of 1,500 per year is almost 50% higher than the Institution's estimate and will be realised, at present rate of growth, in about 13 years' time.

Let me draw your attention to one other vital problem—the "export" of Production Engineers. Professor Richards, of the University of Southampton, said at the recent Conference[3] that "one third of his graduates went to design and research, one third to production, and the remainder to Canada ! " Surely it is highly desirable that the Commonwealth should want our trained men, and that we should encourage this flow, particularly as such men, being influential users and buyers of equipment will remember the Old Country in a very practical way.

I am told that South American families once sent their sons to be trained in Britain : today the tendency is for them to be sent to the U.S.A. Surely this is a bad thing in many ways; the remedy is to add to our training load a substantial 'export quota'.

Whether you take the minimum requirement of 1,100 trained Production Engineers per year or, I suggest, a figure nearer 2,500 per year, the same urgent attention is needed to uplift our training plans. Failure to do so makes nonsense of the term 'an expansionist policy for production'.

And now, having stated our greatest problem, what more are we going to do about it ?

To the Managing Director of almost any type of company may I suggest, with every diffidence, that there is an intimate connection between the Sales and the Production Directors. (I am quite sure you have someone on your Board who is the chief production executive). Every change in your product, every 'tough' delivery quoted by Sales, either in price or time, becomes a challenge to the producer. Are you satisfied that your production people have enough training and status to solve your future problems ? If not, are you giving the right sort of encouragement to close the gap ?

2. "Research and Development in British Industry". 3. Southern Section Aircraft Conference (see pages 83/104 this issue).

To the Personnel Officer, may I suggest that a closer study of departmental needs over the next few years may show that the present shortage of trained production men will continue. You may decide that advertising for them must be reinforced by an energetic guidance of more of your young people into the production field where so many opportunities exist.

To the Principal of the Technical College, may I suggest that your oft-repeated lament on the failure of industry to take advantage of your production training facilities may be overcome by better salesmanship on your part. They are, after all, customers. I would particularly suggest to those Principals who have not yet fully recognised Production Engineering as a career of great importance, that they should follow the impressive lead being given by so many famous institutions. There are still less than 50 colleges offering Production Engineering courses against 200 for, let us say, electrical engineering.

I have reserved until the end my appeal to those many public-spirited production executives who have so much to give to those young men who want, so much, to receive.

One of the greatest difficulties of any new technique is finding enough practitioners who can both practice and preach. Every Production Engineer of worth is today working hard at his main job, and has little inclination and less financial encouragement to run the 'second mile' of part-time teaching. Firms can help greatly by encouraging their senior men to give time to this work, which brings much needed and appreciated practical experience into the educational field. But there is no substitute for personal enthusiasm, which can be made evident in a variety of ways. Papers can be written, which have the added virtue of showing the writer how little he knows; contributions to the press can be of great value to author and reader.

All these activities and others too will spark our much needed programme for supplying more and better Production Engineers, and in a few years we shall be thankful we intensified our efforts in 1953.

At the beginning of a new year we look backwards as well as forwards. Here we have been looking forward; in taking a peep over your shoulder into the past you may well agree that the happiest memories of your business life are centred around, not the things you have designed or produced, not the systems you have devised, but the *men* you have helped to train.

The Right Hon. Viscount Nuffield

G.B.E., M.A., Hon.D.C.L.Oxon., Hon.LLd., D.L., K.St.J., F.R.S., F.R.C.S., Hon.M.I.Prod.E.

An Appreciation by
THE RIGHT HON. LORD SEMPILL, A.F.C.,
F.R.Ae.S., Hon.M.I.Prod.E.

OVER 40 years ago, I was serving my time as an apprentice with Rolls-Royce at Derby under the late Sir Henry Royce and Mr. Wormald, then the Works Manager. In those days Mr. Hives was in charge of the experimental Department, today of the Company as Lord Hives, the Managing Director.

I worked at the bench under Mr. Hives and then, as now, he always knew what was moving in the technical field and told us of one William Morris, in Oxford, who was developing a small car with the idea of making motoring possible for those who could not aspire to the ownership of a Silver Ghost.

We would all like to think that we had the vision of William Morris and say, in those early days, that the Morris Oxford would capture first, the imagination of the British public and second, of the motoring world.

After this, I can well remember how we on the floor of the shop kept our ears glued to the technical grapevine for news. We had great pride in the fact that William Morris of Oxford, who started in the

bicycle world, as did Henry Ford of Detroit—the world's first mass producer of motor cars, was determined to show that the Old Country could make its mark in the development of road transport, as it had done in rail, and is doing today in this jet-propelled supersonic age.

I first met William Morris in the 1914/18 War, and was captured by his vision, modesty and burning zeal to serve his fellows.

Although I have never had the good fortune of my pilot friend, Sir Miles Thomas, to have served under Lord Nuffield, it has been my privilege to work with him and to be concerned with many developments in the field of the humanities and technology, and on all of these Lord Nuffield has come to exercise a beneficient influence. I can think of many occasions when several of us have struggled with what we felt was a good cause, and eventually were faced not only with the problem of making progress, but of keeping what we thought was a great ideal from sinking into inactivity and possible ultimate oblivion. If our ideas were sound, and we were very lucky, Lord Nuffield took an interest. When he appeared on the scene of activity, difficulties that seemed insurmountable became manageable. His unwavering faith and vision gave us that confidence that inspires success.

It was such a picture as this that faced those of us who pioneered in the early days of the Institution of Production Engineers with our first General Secretary—Richard Hazleton. We were all convinced that if Lord Nuffield could be persuaded to lead this newly-formed Institution, it would never look back. With this object in view, we strove the harder to establish its technological position among the Institutions of our country and, in fact, the world, so that when we came to invite Lord Nuffield to accept nomination as President of the Institution, our request could have but one answer !

The privilege of persuading this remarkable man to add yet another task to the very many already on his shoulders fell to me. I have never approached an interview with more nervousness, since I knew that the word " yes " would put the Institution on the road to success from which it would go forward from strength to strength; but that a refusal would mean we should have to continue, perhaps for years, struggling in the background.

Good fortune was on the Institution's side, since it was striving to advance a cause, the importance of which to the future of our country could not be overstressed. Lord Nuffield consented. As the then President, I had the privilege of relinquishing office to one of the historic figures of our day, destined to assure the position of the Institution in the hierarchy of British technical societies, and to herald a new era in its affairs.

With that thoughtfulness which characterises his every action, he saw that the Institution could only build on a solid foundation, and he first made possible the acquisition of the Institution's Headquarters in Portman Square and second, founded the Research Department, with a highly-qualified Director, at Loughborough.

The Institution's position rests on foundations laid by Lord Nuffield and, in later years, members joining will know his name as we today know those of, say, Watt and Stephenson. The membership will, however, be reminded of its debt to Lord Nuffield when they assemble annually to hear read the Paper which carries his name.

Lord Nuffield has announced his retirement from the Chairmanship of that vast organisation which he and the late Lord Austin built up. As one having the pleasure of his friendship, I can smile at the idea of retirement ! Such would indeed be a heavy blow to industry, but we can understand that by not clouding his mind with innumerable daily problems with which the younger generation must grapple, his unique experience would be available to plan the future of the industry which he played a major rôle in establishing.

We need Lord Nuffield's continued inspiration and I am convinced that industry can look to him for guidance in the years ahead. The keynote of his life is faith. As the late Sir William Osler wrote 50 years ago:

> *" Nothing in life is more wonderful than faith—the one great motive force which we can neither weigh in the balance nor test in the crucible ".*

HOW THE PRODUCTION ENGINEER CAN BE HELPED BY THE METALLURGIST

by Dr. J. D. JEVONS, B.Sc., F.R.I.C., F.I.M.

Presented to the London Section of the Institution, 10th April, 1952.

Dr. Jevons is Chief Metallurgist to Joseph Lucas, Limited, and head of the central chemical and metallurgical laboratory of this concern and its associated companies. His published work includes "The Metallurgy of Deep Drawing and Pressing", published both here and in the United States of America, and numerous papers to learned societies and articles to the technical press on deep drawing and pressing, heat treatment, welding, and other metallurgical subjects.

He is a Fellow of the Royal Institute of Chemistry; Fellow of the Institution of Metallurgists; Member of Council, and of the Development and Publications Committees of S.A.S.M.U.T.A. He also serves on the P.E.R.A. Committee on Metal Forming; the B.I.S.R.A. Committee on Sheet Metal Working; the B.W.R.A. Committees on Fundamentals of Spot Welding and on Projection Welding; and the B.N.F.M.R.A. Committee on Deep Drawing of Aluminium.

Dr. J. D. Jevons

WHEN I started to write this paper I did what all writers of papers are supposed to do, and made a framework on which to build my story. The first list of major headings was a very long one, and the addition of sub-headings lengthened it many times. By the time the next set of sub-divisions had been filled in it became evident that, if the paper was to be of normal length, it would consist of a lengthy syllabus with little or no discussion of the many items included in it.

A paper of that kind is, I think, the most boring of any to listen to. So, instead of attempting to deal with my subject systematically and comprehensively, I have chosen a few somewhat random examples of how the metallurgist can be of service to the Production Engineer in the hope that by illustrating ways and means, these will suggest many others to you. In these examples I have purposely devoted most space to aspects which seem to me to be less obvious than the recognised, though unfortunately often neglected, ones such as choice of materials, heat-treatment, machining, welding, plating and, because it was covered to a considerable extent in my last paper to you, deep drawing and pressing.[1]

Although for many years it has been my strong and oft-expressed belief that very great benefit would result from much closer collaboration between designers, Production Engineers and metallurgists, I must confess that even I was surprised at the length and, speaking metaphorically, at the breadth of the syllabus that I have just mentioned. I feel more strongly than ever that in almost every instance in which the Production Engineer uses metal and has not discussed his particular needs with the metallurgist, he would benefit by doing so.

Advising on the best material to use for any given component, having regard not only to its function but also to the processes which are to be used in its manufacture, is so obvious a way in which the metallurgist can, and should, help both the designer and the Production Engineer that I am going to make only one brief comment on this very important matter. This is to express surprise that so often this help is not sought because it is considered that no help is needed, and that all that need be done is to look in a book of specifications and select, for example, some steel which has, or can be heat-treated to give, certain mechanical properties. The fact that certain steels can be manipulated, worked and heat-treated more easily than others in the plant which happens to be available ; that physical properties are influenced profoundly by change of section ; that some steels are more susceptible than others to unwelcome phenomena such as retained austenite when hardened, or to surface deterioration when immersed in cyanide ; that some are more prone than others to crack or to distort, and allow

more latitude during heat-treatment: these and other facts are not understood or, if they are, often seem to be ignored by those who select the materials with which the Production Engineer has to deal.

Leaving this major and obvious issue, the purpose of this paper will be served best if less obvious, but nevertheless important, matters are discussed. First, then, a few thoughts on how the metallurgist can help the Production Engineer at the very inception of some new component.

Designing to Facilitate Production

Sometimes the designer consults the Production Engineer when a component is still on the drawing board. Less frequently, he consults the metallurgist. If he would always consult both, preferably together, it would be found that in most instances production costs could be reduced and many of the usual production troubles could be avoided. When a component has actually gone into production, quite often it is too late to alter either its shape or its method of construction or manufacture, because this would affect other components or would necessitate the scrapping of expensive tools or plant.

While a component is still on the drawing board, the knowledge and experience of the Production Engineer and the metallurgist will often enable them to suggest alterations which, though perhaps simple and without significant detriment to the functioning of the part, will transform what would have been a constant source of worry for the Production Engineer into a smoothly flowing job free, even, from serious "teething troubles."

In the instance of parts which have to be formed by cold-working operations such as deep-drawing, pressing, heading, or merely simple bending, a small and often functionally unimportant change in shape may make a very big difference to the ease or otherwise of manufacture. This will be reflected in the number of operations needed, in whether or not interstage annealing has to be given, and in the quality or grade of the material used.

To illustrate this point, consider bending, the simplest forming operation of all, yet one which often causes quite a lot of trouble. Cracking, such as that seen in the "close-up" view of a bend in a small blanked mild steel lever illustrated in Fig 1,

Fig. 1

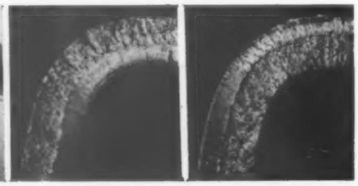
Crack at bend in small component blanked from mild steel sheet.

is quite common, particularly when the metal to be bent is not in the fully softened condition. In this connection, the curious foible of designers to make radii smaller than they really need must be firmly resisted.

It is well known that under given conditions sheet can be bent, without cracking, to a substantially greater degree in a direction at right angles to that in which it has been rolled, than it can in one parallel with that of rolling. Fig. 2, which shows two bent specimens cut from the same piece of steel sheet, one at 0 and the other at 90 degrees to the so-called "grain," demonstrates this clearly. The direction of "grain" should be, and usually is, marked on the drawings of bent components; but, particularly when follow-on press tools are used, Production Engineers have been known to change the specified direction in order to facilitate the design and construction of their tools, or to reduce the amount of discard. The choice of the orientation which will give the best compromise between the several

x2

Fig. 2



x2

Fig. 3

Fig. 2. Strips blanked from the same piece of low-carbon steel sheet and bent, "burr" on inside of bend, over the same radius till cracks appear:
***above*—strip cut at right angles to direction of rolling;**
***below*—strip cut parallel with direction of rolling.**

Fig. 3. Strips blanked in the same direction from the same piece of low-carbon steel and bent over the same radius to the same angle:
***left*—deep cracks produced when "burr" on sheared edge is on outside of bend;**
***right*—absence of cracks when "burr" is on inside of bend.**

opposing factors which usually are involved is one which the designer, the Production Engineer and the metallurgist should discuss while a component is still on the drawing board, and the grade of metal still under consideration.

A considerably sharper bend can be made when the "burr," which is always present on one side of a sheared edge, is on the inside of the bend than when it is on the outside. If the blanks are fed so that the burr is on the outside, cracking occurs as shown in the enlarged view of the bend made in a piece of $\frac{1}{4}$ in. thick low-carbon steel strip, shown on the left of Fig. 3. If the burr is on the inside, no cracking occurs under similar conditions of bending, as can be seen on the right of the same illustration. Besides putting the direction of rolling on a drawing it is, therefore, often necessary to include as well the direction of shearing of the blank, and to make certain that both these instructions are in fact always carried out.

A number of minor yet not unimportant factors have not even been mentioned, but enough has been said to show that, even in the making of a simple bend in a strip of metal, many production difficulties can be avoided if the designer, the Production Engineer and the metallurgist together discuss any new component *while it is still on the drawing board.* Needless to say, discussions of this kind are of even greater value when cold-forming operations of a more severe and more costly nature than bending are being planned.

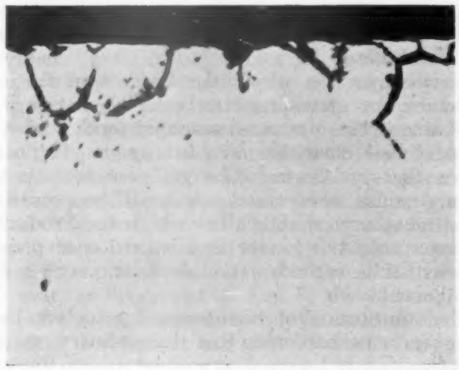
When parts have to be heat-treated, discussion at the drawing board stage could save a large proportion of the troubles which are so often experienced in heat-treatment shops. For example, the likelihood of cracking during hardening can often be reduced quite substantially by putting a radius on corners which need not really be quite sharp, by avoiding abrupt changes of section and, sometimes, even by separating two or more stress-raising features which need not really be so close together that their influence is combined. Sometimes more fundamental changes, such as a substantial reduction in the difference between the thickest and the thinnest sections of a component, or the elimination of blind holes, can be made with considerable benefit to all. The considerations just mentioned apply with greatest force to steel parts which have to be hardened, but they may also be of very considerable importance in determining both the soundness and the freedom from cracking of many metals during casting, and even during many forging and welding processes.

When small components of varying section have to be case-hardened, it happens quite often that the designer overlooks the fact that if the case depth he asks for is given to the thicker sections of some part, there will be little or no core left in the thinnest sections, as in the example shown in Fig. 4. It seems elementary that this point should always be checked while any new component is on the drawing board, but it is often forgotten.

x6

Fig. 4
Diametrical section through small case-hardened steel component etched to show complete absence of core in the thinner sections.

Another common difficulty is that designers often specify tolerances on case depth, which cannot possibly be held under ordinary production conditions with the plant that happens to be available. Sometimes this is done in an attempt to secure at least a little core in a thin-walled article ; but when there is an ample core, it seems to be done for no reason at all. At present, case-hardening is *not* a so-called " precision " operation. If, in the carburising of large numbers of small articles to depths in the region of 0.020 to 0.030 inch a tolerance of plus or minus 10 per cent. is held, this can be considered as being good. In many shops, double this value is all that can be achieved, despite the taking of all reasonable precautions ; in some, even these quite wide limits cannot be guaranteed. Wider recognition of this difficulty is needed.



x500

Fig. 5
Unetched section of cyanide-carburised alloy-steel component showing intercrystalline attack penetrating inwards from surface.

If cyanide baths are checked frequently for strength and are maintained at a constant temperature it will, in most instances, be possible to achieve a closer control of case depth in them than it will in pots packed with solid compound. A word of warning must, however, be given concerning the indiscriminate application of the cyanide method to alloy steels, particularly to the more highly alloyed case-hardening steels, which are likely to suffer a peculiar intercrystalline surface attack, as illustrated in the microsection shown in Fig. 5. Unless the time of heating is very long, the depth of penetration is quite shallow, and the defect is completely removed by even light grinding. When components known to be highly stressed are *not* ground after case-hardening, the safety of the cyanide method should be seriously questioned, because surface defects of this kind can act as "" stress-raisers " and may well start a fatigue crack.

In pack, as distinct from cyanide, carburising, more careful choice of both the size and the shape

of the pots in relation to the size and shape of the components to be carburised, would often secure a more uniform depth of case. It is a pity that much more extensive use is not made of carburising pots specially shaped to suit the work placed in them. The simplest example of this practice is the use of a tube to hold a long camshaft, and an annular or ring-shaped hollow container to hold ball races of large diameter.

Important though pots are, it often happens that the principal cause of variation in case depth lies in an uneven temperature throughout the carburising furnace in which the pots are heated. Here the metallurgist can help by measuring the case depths produced in different pots and putting these on a map of the furnace hearth. On the hearth of one quite modern furnace mapped out in this way the variation in case depth was found to be no less than 40 per cent. After several rearrangements of the heating elements had been tried this was reduced to 10 per cent., but this was the best that could be achieved.

Choice of Manufacturing Methods, Processes and Plant

Another way in which the Production Engineer could use the metallurgist to better advantage is by discussing with him new methods, and even new plant, *before these are decided upon.* Do please notice that little word "before," because upon it often depends whether or not it will be possible to avoid metallurgical difficulties which the Production Engineer may not foresee and which, once plant is installed and methods established, may cause continual trouble.

The substitution of high-frequency surface hardening for case-hardening by the ordinary method of carburising and quenching, can be used to illustrate this point. Local surface hardening by high frequency methods is very attractive to the Production Engineer, because he can put the quite compact apparatus actually in his production line, thus avoiding transport to and from a remote hardening shop ; because selective hardening of certain areas is often simple; because the method is quick and clean and also, let us whisper it, sometimes because he likes to show visitors what really up-to-date plant he has in his shops.

But consider the other side of the balance sheet. The low-carbon case-hardening steel will have to be replaced by a considerably more expensive medium-carbon steel, which will not machine nearly as readily and may well mean halving the output of certain machine tools. Indeed, when using the higher carbon steel the available machining plant may not be able to give the needed output, and the purchase of extra tools will swell the already high cost of the high-frequency unit many times. Operations such as broaching, splining or thread-rolling may prove very difficult indeed.

Here the metallurgist can help by suggesting the use, should conditions allow, of the more easily machined, but unfortunately even more expensive, lead-bearing or extra high sulphur medium carbon and alloy steels. He can also point out certain difficulties which may arise in particular instances. Some of these, such as the much lower capacity of the medium carbon steel to suffer operations which involve plastic deformation, such as staking, heading or the rolling-in of worms or threads, or the fact that the strength of the core will not be increased as usually happens during ordinary case-hardening, may be ones which the Production Engineer knows, but can easily overlook. Others, such as the serious embrittlement of surface-hardened shafts owing to the inflow of heat from the surface inducing strain-ageing effects in the "core," are ones which he might well be forgiven for not having thought of.

The choice between various ways of case-hardening such as carburising by the pack, the salt bath or the recently introduced gaseous methods, and perhaps by nitriding ought, if considered properly, to involve considerations of a more involved metallurgical nature than the average Production Engineer will be aware of. Neither this nor other examples which will no doubt come to mind can be considered here, but I hope that the remarks on high-frequency hardening will serve to indicate how the metallurgist can often offer guidance, sometimes in unexpected ways, in matters connected with the choice of methods and plant.

One brief plea to end this section. Do allow the metallurgist to have full authority in planning the essential feature and layout of any shop or space devoted to heat-treatment. Prompted by the very commendable desire to secure a neat and orderly arrangement of plant, planning engineers sometimes do things which will cause endless trouble. For example, they have been known to place a quenching tank so far away from one of the furnaces it has to serve that, no matter how great the agility displayed by the hardener, properly hardened work could not be guaranteed. Again, in order to reduce the number of salt baths and to arrange equipment in neat rows, it happened once that a rearrangement

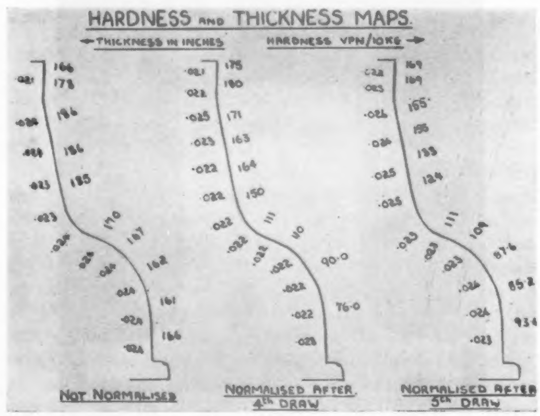


Fig. 6

Hardness and thickness maps prepared from measurements made on the walls of deep-drawn fore-cups normalised at different stages.

was planned whereby work from a cyanide bath was to be quenched in a nitrate bath. Fortunately, the metallurgist happened to see the plan in the planner's office ; and, as far as I know, the roof is still on the hardening shop where the change was to have been made. Spoken of in a lecture, affairs such as these seem almost fanciful; but I assure you that they really do happen.

Starting New Products and Processes

When new products or processes are being started, the metallurgist can nearly always be of very real assistance to the Production Engineer in helping to establish the best conditions for very many kinds of operations and processes. By means of sections, hardness measurements and metallographic examination, he can generally guide the tool designer and can say at what stage interstage annealing becomes, if not an actual necessity, a wise precaution in all kinds of cold-forming operations. For example, in the production of a certain bomb fore-cup, the making of hardness and thickness maps of the kind illustrated in Fig. 6 played a useful part.

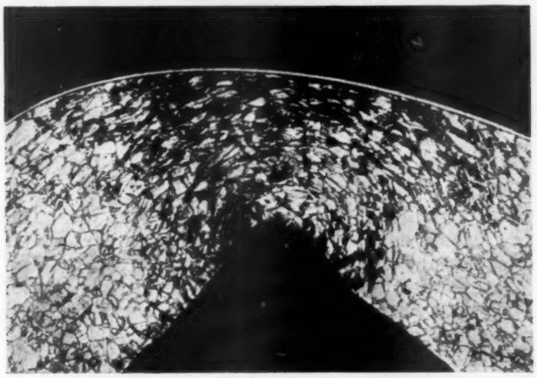


Fig. 7 x75

Section showing that a proposed method for forming a right-angle shoulder in the wall of a brass pressing caused a dangerous amount of thinning coupled with intense local deformation.

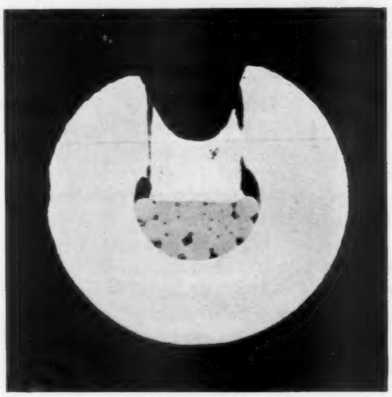
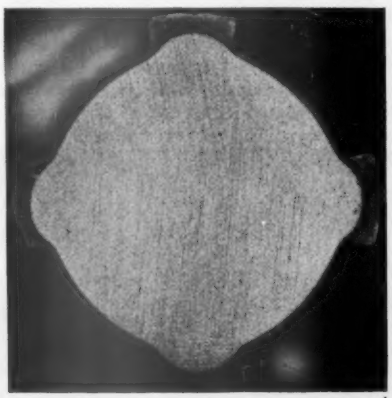


Fig. 8 x10

Transverse section through cable and socket of brass terminal showing unsatisfactory gimping.

Quite often those who are responsible for methods and production think out new ways for doing things by cold-forming which, seen from the surface, appear to be satisfactory and capable of achieving substantial economies. Although it generally makes him unpopular, the metallurgist can sometimes give warning that a proposed method is unsafe. For example, the section illustrated in Fig. 7 showed that a proposed method for forming the bend in the wall of a brass pressing had not only caused intense local work-hardening, but had thinned the wall at the bend to less than half its assumed thickness. Another section, illustrated in Fig. 8, showed that a proposed gimping operation to squeeze a tube on to a cable end had, in fact, sheared a strip right out of the wall. By etching sections, he can reveal what is popularly termed the "grain" or the "flow" of the metal, and hence is able to suggest alterations to dies or to procedure which will facilitate, and perhaps cheapen production, reduce the likelihood of cracking during subsequent manufacturing operations, and probably strengthen the final product.

In the matter of heat treatment, he can usually specify general conditions and then proceed, by experiment with actual prototype components, to determine precisely details such as soaking periods and exact quenching and tempering temperatures, and which of perhaps several heat-treatments is best. Using the method and plant allocated for the case-hardening of a new component, he can determine the exact conditions which are required to give a case of the desired depth. The same can be followed when surface hardening is done by high frequency methods ; and with these there is the added advantage that, as illustrated in Fig. 9, the contour and depth of the hardened surface layer around changes of section is revealed, and the effect of changes in the shape of the heating coil can be studied. When, as often happens, he has had past experience with both the steel and the plant, the metallurgist can usually say fairly definitely to what hardness or other limits it will be possible to work under the



x4

Fig. 9

Transverse section through splined shaft etched to show depth and contour of surface-hardened zone produced by high-frequency heating.

production conditions which obtain, for these, let it be understood, are seldom the same as those under which single, closely watched prototypes are treated.

The brevity of these remarks on how the metallurgist can help when a new product or process is going into production, must on no account be taken to mean that this aspect is of little consequence. In fact, it is one of the most important of any: for if a new product or process is put into production, without those who have to run it having been given clear instructions as to exactly what is to be done, and what the result must be, continual trouble is likely to be experienced. What is more, those who are in control will soon form their own ideas and it will be very difficult indeed to obliterate these ideas when, later, proper instructions are issued.

The Danger of Stamped Identification Marks

The stamping of identification marks on the surface of many kinds of components in an indiscriminate manner is responsible for quite a large number of failures ; all wasteful, many expensive, and some so serious as to involve loss of life. Identification marks can cause failure in two ways, namely, by fatigue during service or, if the part has to be hardened, by cracking during heat-treatment. Both these two quite different kinds of failure have a common origin, namely, the well known tendency of notches to act as local "stress-raisers."

Dealing first with fatigue failures, a belief exists that stamped marks are dangerous only on *hardened* components. Although there is an unquestionable tendency for the danger of stamped, and even of etched, marks to increase as the ductility of the component bearing them decreases, which in general means as the hardness increases, it must never be assumed that normal precautions in the placing of these marks can be relaxed when the parts being marked are soft. By way of illustration, Fig. 10 shows a typical fatigue failure, caused by letters punched in the surface of a soft low carbon steel bracket which, but for the presence of these stress raisers, possessed ample strength to carry out its allotted function.

Identification marks made by electric or chemical etching are nearly always much less dangerous than stamped marks, because their edges are less well defined and because they are, as a rule, much

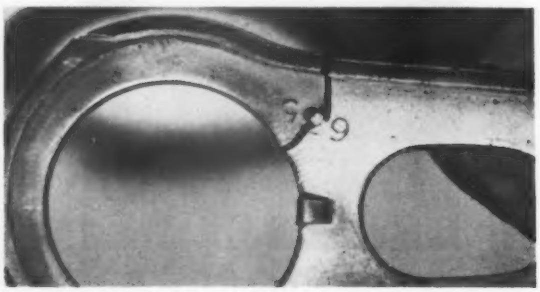


Fig. 10
Fatigue crack in soft mild steel bracket caused by stamped numerals.

shallower. These methods should, therefore, be chosen for the identification of all highly stressed components. Even then, care should be taken to ensure that marking is done in a position where the service stresses will be as low as possible.

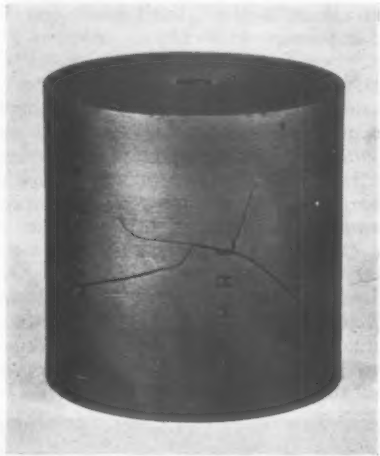


Fig. 11
Hardening cracks caused by letters stamped on steel heading die.

Dealing with the second risk, cracking during hardening, the dangerous effect of stamped identification marks has long been known. Yet, year after year, much money is wasted, much time is lost and much acrimony occurs, for no reason other than that identification marks are still stamped on and, as often as not, stamped on in particularly dangerous positions on both tools and components. How dangerous marks of this kind can be, even when they are placed in a supposedly safe position, is well illustrated by the plain cylindrical cold-heading die shown in Fig. 11. Normally, the hardening hazard for a tool of this shape would be virtually negligible and, if cracking did occur, it would be at the sharp internal fillet of the recess at the end of the bore. The influence of the marks stamped on the side of the die can be judged from the picture.

In simple tools or small components, hardening failures of this kind are merely annoying. In complicated tools costing perhaps several hundred pounds, they are lamentable. Applied to parts which, if they failed, might well mean the wrecking of an aircraft engine, the adjective "lamentable" may well seem inadequate to the pilot of a single-engined 'plane. Fig. 12 shows a section cut through a letter stamped on a steel component, which subsequently was hardened. Observe the hardening cracks starting at the indentation which, in a highly stressed component, would almost certainly spread to cause failure.

"Stress-Raisers": Their Nature and Effect

Identification marks, which we have just considered, are by no means the only form of stress-raiser

Fig. 12 x50

Section through stamped identification numerals on steel component showing hardening cracks formed during subsequent heat-treatment.

with which the Production Engineer is closely concerned. Four common faults to which the metallurgist sometimes has to call his attention—very tactfully, of course—are tool marks, badly sheared edges, rough machining and the making of a sharp fillet where a radius is called for.

Tool marks are well illustrated by the notch seen in the coil spring shown in Fig. 13. In a dynamically loaded spring, injuries of this nature can be very dangerous indeed. Marks of this kind are by no means confined to bending operations : tools used to grip and even to guide, sometimes leave dangerous dents or scores if insufficient care has been given either to their design or to their maintenance.

The influence of surface finish on the fatigue strength of components has been discussed so often in engineering literature that comment here would be superfluous, but may I remind you that even though a certain standard of finish has been agreed upon, it happens sometimes that, owing to some mishap or to neglect or carelessness, some components have tool scores or rough machining on, perhaps, only one small part of the machined surfaces. If this area happens to lie in a highly stressed zone, for example at a fillet or at the mouth of a hole, it may well lead to failure by fatigue.

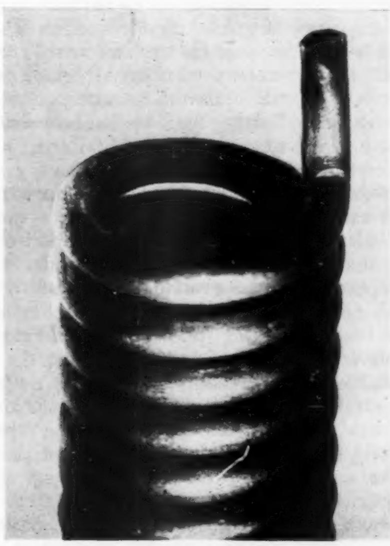


Fig. 13

Notch caused by tool used to form extremity of cold-wound steel spring.

The metal in the " burr " of a badly sheared edge is intensely work-hardened and, even though they cannot always be seen with the naked eye, full of tears and actual or incipient cracks which form ideal starting points for fatigue cracks. For this reason it is unwise to have a sheared edge on stressed components such as leaf springs, because its presence may well lead to failure. If, for some reason, rolled-edge strip cannot be used for parts such as leaf springs, the " burr " should be removed from the edge of sheared strip by means of some suitable dressing operation. The presence of badly sheared and undressed edges on a component which has to be hardened, for example on a Belleville washer, is particularly dangerous. On the other hand, it can also be dangerous on quite soft metal, a fact sometimes demonstrated by the failure of the brass cages in ball races, when the condition of their sheared edges happens to be unusually bad.

In these days, most designers realise the weakening influence of a sharp fillet at changes of section in a dynamically loaded shaft, or indeed in any form of component. Because it is much easier to turn a sharp fillet than a smooth, nicely blended radius, and because human nature is what it is, it sometimes happens that, maybe in the course of time, what appears as a radius on a drawing becomes a sharp fillet on a component. Unhappily, the consequent welcome reduction in the time and cost of machining may well be offset by fatigue failures, engendered by increased stress concentration. May the metallurgist plead that, no matter what economy or other manufacturing benefits may result, no radii be omitted from any stressed component without the knowledge and consent of its designer ?

Cracks : Their Origin and Danger

Sometimes the Production Engineer wants to know the origin of cracks which have led to a part being rejected during inspection, or perhaps have caused it to fail during service. He may, for example, be blamed for having through faulty treatment produced hardening cracks when, in fact, failure has been caused by the fatigue of a perfectly sound, but badly designed or perhaps overloaded component.

Metallographic examination can usually decide this question for, except in rare instances, these two kinds of cracks have different characteristics. The section seen on the left of Fig. 14 shows the appearance of a typical fatigue crack, which has started at a radiused shoulder in an overstressed shaft. Observe the straightness of this crack, which runs purposefully through the metal, taking no notice of its structural features. The section on the right of this photograph shows a microsection through a typical

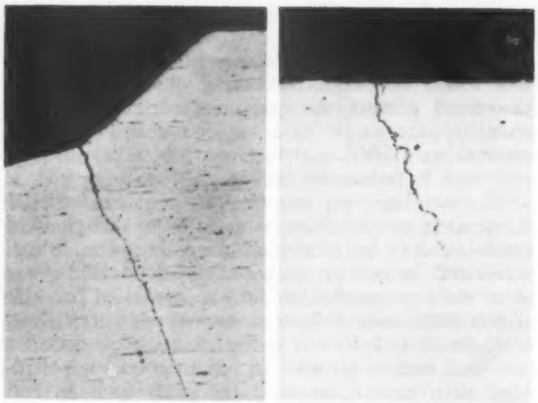


Fig. 14 x100

Unetched sections through steel components showing characteristic features of (*left*) a fatigue crack and (*right*) a hardening crack.

hardening crack. Notice the characteristic zig-zagging, caused by its tendency to follow the crystal boundaries of the steel as they existed at the time when the crack was formed.

In the diagnosis of suspected grinding cracks, the appearance of the cracks on the surface of the component, as distinct from on a cut section, is often most helpful. Grinding cracks usually run more or less at right angles to the direction of travel of the grinding wheel, as seen on the left of Fig. 15 or, occasionally, exhibit a so-called "crazed" appearance. Contrast the appearance of these cracks with that of the ones, on a similar component, seen on the right of Fig. 15 for which the Production Engineer was, I am sorry to say, blamed almost

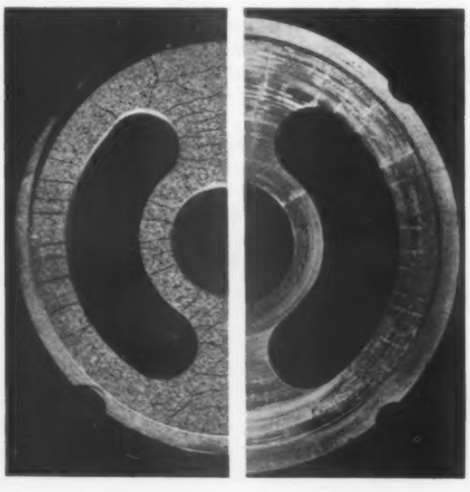


Fig. 15

Appearance of surface cracks on steel component caused by:
***left*—harsh grinding during manufacture, and**
***right*—thermal stresses encountered during service.**

automatically. Fig. 16 shows a more striking instance, for the series of parallel cracks seen on the skirt of this piston might well be chosen as being really typical of ones attributable to harsh grinding. Notice, however, that the piston has been ground circumferentially and, therefore, that the cracks run parallel with, and not across, the direction of travel of the wheel. In both the happy instances just illustrated, the metallurgist was able to show that the cracks had been caused not by grinding, but by thermal stresses arising from unusually severe running conditions.

Fig. 16

Cracks on skirt of steel piston caused by thermal stresses encountered during service.

The Production Engineer sometimes asks whether shallow grinding cracks, and indeed other kinds of cracks, are really dangerous, and whether the presence of perhaps just one or two small cracks justifies the scrapping of expensive, urgently needed components right at the end of a long and troublesome production sequence. Generalisations are always dangerous, but there can be but few instances where it would be possible to say with complete confidence that a crack present in a highly, or even moderately, stressed engineering component subjected to dynamic loading will be unlikely to spread and thus, in time, to cause a fatigue failure.

The lower picture in Fig. 17 shows grinding cracks at the corner of a hole in a certain hardened steel ball race housing. The diameter of the hole is about half an inch, and the cracks themselves were so small that they passed unnoticed under careful visual inspection of the ground surface of the boss. Acid etching was needed to enlarge them to the condition seen in the photograph. The upper picture shows what happened to many of the housings in this batch during service. I hope the reproduction is sufficiently clear for you to see, from the characteristic fatigue markings, that the creeping fracture did in fact start from the edge of the hole, where the grinding cracks which acted as unwelcomely efficient "stress raisers" were situated. This example will, I hope, demonstrate how dangerous even small cracks can be in highly-stressed, dynamically-loaded components.

In the case of low-stressed statically-loaded components, the making of decisions as to whether certain

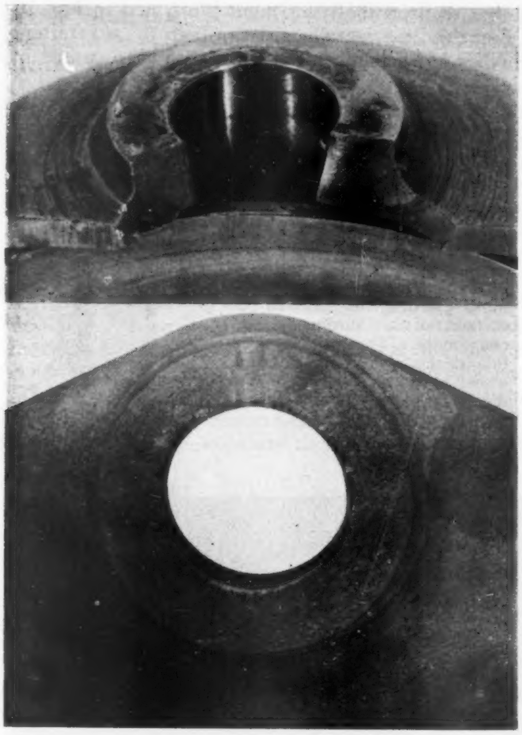


Fig. 17
A demonstration of the danger of even small cracks in highly stressed components; fatigue failure of hardened steel trunnion bracket (*above*) traced to existence of grinding cracks too small to be detected by ordinary visual examination, but revealed by light etching (*below*).

cracks constitute a serious hazard is, paradoxically, often far more difficult. In soft ductile metals, the danger of a crack spreading with time under a low service stress is much less than in, for example, a hardened steel component which will be far more " notch sensitive " and will probably contain internal stresses of considerable magnitude. For example, a slightly cracked hardened magnet may suddenly fracture while lying in the stores, whereas cracks in a car foot-well pressing may be so innocuous that it would be a waste of time to weld them up.

The Influence of Microstructure on Machinability

In no way perhaps can the Production Engineer work in such close collaboration with the metallurgist to achieve such obvious and indeed, sometimes amazingly beneficial, results as in the field popularly described as " The Influence of Microstructure upon Machinability." The fundamental aspects of this can be studied with the help of the metallurgical microscope and of electrically-controlled dynamometer equipment applied to a cutting tool ; but, disregarding for the moment such fundamental matters as " tool life " and " power consumed," the Production Engineer is often faced with the immediate and practical problem, that identical components machined under identical conditions from consecutive deliveries of steel ordered to the same specification, and having virtually the same mechanical properties as measured by the commonly applied laboratory acceptance tests, behave very differently. They may, for example, come off the machine with a very different, and in one instance unacceptably poor, surface finish. When this happens, metallographic examination often reveals some significant difference in microstructure which is causing the observed difference in machinability. Unhappily, microstructure is not yet covered by generally acceptable specifications, but in spite of this private arrangements can often be made with steel suppliers, which will ensure that at least the major portion of the steel supplied has the microstructure best suited to the particular needs of the consumer.

The metallurgist feels that a much more active interest ought to be taken in this matter ; but, eager though he is to play his part, he must give a warning that this whole subject is one of great complexity and that no simple rules of behaviour can yet, and perhaps may never, be established. Part of the complexity lies in the fact that, to obtain the best results, different machining operations, such as turning, drilling and broaching, each need a different kind of microstructure in a given steel ; that this structure may vary, even in its basic nature, from steel to steel ; that different tool materials, such as high speed steel, carbide, and even different grades of carbide, need a different microstructure ; and that cutting speed, feed, lubricant and sometimes the rigidity of the tool in relation to the work, each exert an influence of their own which is superimposed upon those of all the other variants, and makes their isolation and study still more difficult.

To illustrate the complexity of the problem, may I refer to the results of some machinability tests described by the Curtiss-Wright Corporation in a book published by them in 1950.[2] Only one steel, SAE.8640, containing approximately 0.4 per cent. carbon, 0.9 per cent. manganese, 0.5 per cent. chromium and 0.2 per cent. molybdenum, was investigated. Specimens of this were heat-treated to give six kinds of microstructure, and their behaviour when turned in the lathe with a single point tool was studied by the usual methods.

It was found that when the harder grades of carbide were used, a Widmanstatten type of microstructure having the relatively high hardness of 255 Brinell gave the longest tool life. When the softer and tougher grades of carbide were used, a spheroidised type of microstructure having a Brinell hardness of 160 was better. Best results of all were obtained using a high cutting speed, a Widmanstatten microstructure and a hard grade of carbide, the tool life at a cutting speed of between 300 and 600 feet per minute being about twice that obtained with any other kind of microstructure. Surprisingly, at speeds below 250 feet per minute the softer grades of carbide gave better results than the harder.

When high speed steel was used, a spheroidised structure gave the longest life, this being considerably longer than that given by an annealed pearlitic

microstructure, even though this has the same hardness. Tool life was found to be proportional to the hardness of each microstructural type, a finding which did not hold when the harder grades of carbides were used.

It was found that, with the notable exception of the 160 Brinell spheroidised microstructure which required almost as much power as the 300 Brinell tempered microstructure, for a given feed the power consumed was roughly proportional to the hardness of the steel.

In the important matter of surface finish, it was found that in all instances the hardened and tempered microstructure gave a smoother finish than the annealed structures, the profilometer readings for the two groups being approximately 100 and 150 micro-inches under the particular conditions of these machining tests.

I think these few results will show that it is unlikely that any simple, widely applicable answer to the question of how does microstructure affect machinability will be found for some time to come.

Grinding

Grinding cracks so small that they can hardly be seen with the naked eye can often be made clearly visible by the popular, non-destructive magnetic methods of crack-detection. Because of this it might be thought that the metallurgist can offer little help in the detection and diagnosis of grinding troubles. This assumption is untrue for at least four reasons.

First, the magnetic method may indicate that cracks are present, when in fact there are no cracks at all and the cause of the magnetic disturbance is non-metallic inclusions lying well below the surface.

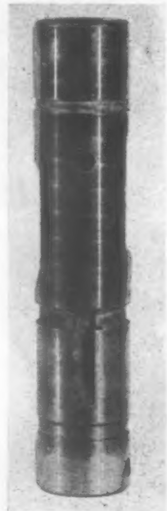
Secondly, when the cracks are very small the magnetic method is not always entirely reliable. For these two reasons alone, whenever a light etch will not ruin an important component, cracks should be sought for by the etching, in preference to the magnetic, method. When etching is not possible it is often a wise precaution to scrap one or two components at the start of production, and even one at intervals thereafter, in order to etch it and thus to ascertain with real confidence whether the grinding technique used on important components is really satisfactory.

Thirdly, magnetic methods of examination do not reveal that often equally detrimental condition where too harsh grinding, although it has not produced cracks, has seriously softened a hard surface. Routine hardness tests are seldom helpful in detecting this not uncommon happening, because the impressions are usually made on an unground area so as not to damage a finely ground working surface. Moreover, tempering is sometimes local as distinct from all over; hence even when hardness tests *are* made on a ground surface, the particular spot chosen for the impressions may lie in an unsoftened zone and, in consequence, the grinding judged to be satisfactory. Etching will always reveal softened areas and sometimes shows interesting patterns, such as that seen on the component illustrated in Fig. 18.

Fourthly, the metallurgist can help by ascertaining whether an incidence of cracking has been caused by bad grinding alone, or whether it is in fact attributable wholly or partly to other causes. For example, when cracking was suddenly experienced in the normally trouble-free grinding of a certain cam, it was established that the cracking was caused not, as was imagined, by some unsuspected alteration in grinding procedure, but by the presence in this batch of cams of a pronounced carbide network in the carburised surface due to faulty carburising. The lower resistance of the defective surface to both thermal and mechanical shock explains why the normally satisfactory grinding technique produced cracks. An overhaul of the case-hardening procedure cured this epidemic ; but observe, please, that the appearance of the cracks was so typical of those produced by bad grinding, that the Production Engineer might well have gone no further and spent weeks in fruitless attempts to discover what had gone wrong with his grinding. By immediately seeking the assistance of the metallurgist, even in this seemingly non-metallurgical trouble, the true cause was quickly found and a serious production hold-up avoided.

Fig. 18

Light etching reveals how harsh grinding has softened the surface of a hardened steel component. The spiral pattern follows the path of the grinding wheel over the surface of the revolving piece.



Deduction of Competitors' Methods

When, as often happens, the Production Engineer wants to find out all he can about the materials and methods used by a competitor, the metallurgist can usually help him if, but as a rule only if, he is allowed to cut up the sample product.

He can find out what materials have been used, measure hardness and, if the size of the sample allows, tensile strength, ductility and perhaps other mechanical properties. This work is obvious and is what would be expected of him ; but, mainly by metallographic examination, he can find out other things. The way in which quite puzzling manufacturing

methods can often be deduced is well illustrated by a certain low-cost needle roller bearing. Chemical analysis had established that the body had been made of low-carbon steel and the rollers of 0.8 per cent. plain carbon steel. Metallographic examination showed that the body had been made from tube; that it had been carburised by the cyanide, as distinct from other methods, to a depth of 0.0035 in ; that it had been given a single quench from below the critical temperature of the core; that the roller retaining flange on one side, seen in section in Fig. 19, had been formed by press tools, *before* the case-hardening operation, and that the flange on the other side of the race had been *rolled* over, *after* case-hardening, as a final operation to seal the inserted rollers in position. As would be expected the hard case had cracked on the tension side of the bend, but the cracks were apparently regarded as being of no danger in a low-duty race of this kind.

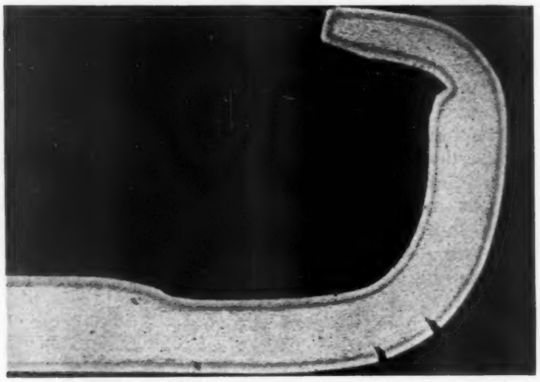


Fig. 19 x20

Etched section of extremity of outer member of needle-roller bearing.

The needle rollers had been hardened right through to a hardness of about 850 V.P.N. but the pointed ends had been locally tempered to a hardness in the region of 550 V.P.N., as shown in Fig. 20, to prevent chipping. The very fine microstructure was indicative of good hardening methods and control, probably assisted by a preliminary treatment to put the steel into the best condition for hardening. The rollers had not been ground after having been hardened, so the complete absence of surface decarburisation showed that they had been hardened either in a very efficient controlled-atmosphere furnace, or else in a non-decarburising salt-bath.

Fig. 20

Etched section of extremity of needle-roller with V.P.N. hardness values.

I hope that this example will serve to show that if the metallurgist is given permission to cut up a component, he can often provide the Production Engineer with quite a lot of information concerning not only the material, but also the manufacturing processes, and even the assembly methods, which have been used in its making. That he can help with the identification of materials is known, but his ability to help in these other ways is perhaps not realised sufficiently widely.

How the Metallurgical Microscope can help the Production Engineer

Quite often the metallurgist and his microscope can give very valuable help in applications which cannot be held to be strictly metallurgical, hence the Production Engineer should not hesitate to bring along any problem which at first sight may seem to be outside the metallurgist's normal province.

For example, the photograph on the left of Fig. 21 shows particles from a lapping paste which behaved badly. Observe the big variation in their size. The photograph on the right shows particles from a satisfactory paste which, as you see, are of nearly uniform size.

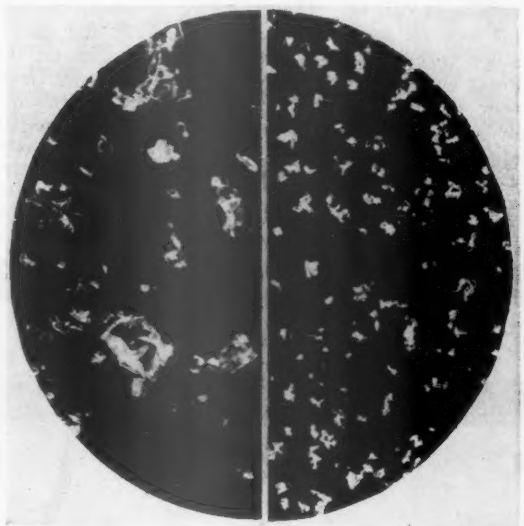


Fig. 21 x100

Photographs of two samples of lapping paste: *left*—unsatisfactory (irregular particle size) ; *right*—satisfactory (uniform particle size).

Shot-peening is becoming an increasingly popular process. After a period of use, the initially round

shot (seen on the left of Fig. 22) begin to fragment (as seen in the centre picture) and soon reach the dangerous abrasive condition seen on the right. By examining shot at intervals during the peening of large numbers of any component, the metallurgist can tell how many each charge of shot can safely peen before it must be discarded.

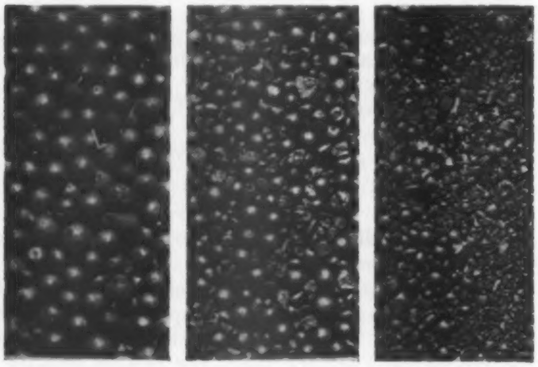


Fig. 22

Photographs of shot used for shot-peening:
left—before use ;
centre—partial fragmentation after period of use ;
right—severe fragmentation after long usage.

Those who are concerned with the winding of fine gauge enamelled copper wire into coils on automatic machines, know how troublesome an epidemic of breakages can be. If, instead of a smooth coating (as seen on the upper wire in Fig. 23), the microscope reveals an uneven condition (as seen on the lower wire), the Production Engineer need not waste time examining his winding machines for obscure defects and trying the effect of alterations which are, in fact, unnecessary. A cross-section will reveal eccentricity of the enamel coating.

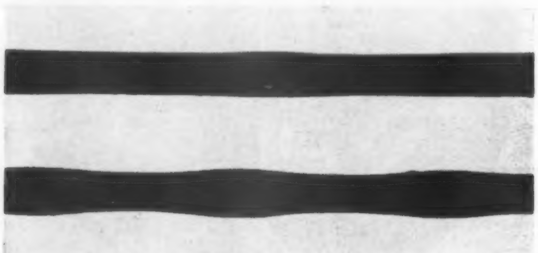


Fig. 23

Photographs of enamelled fine-gauge copper wire for winding coils:
above—even coating (satisfactory) ;
below—wavy coating (unsatisfactory).

Helpful information concerning the soundness, efficiency and consistency of riveted joints can often be obtained by preparing and examining a number of sections. Sometimes, as in the example shown

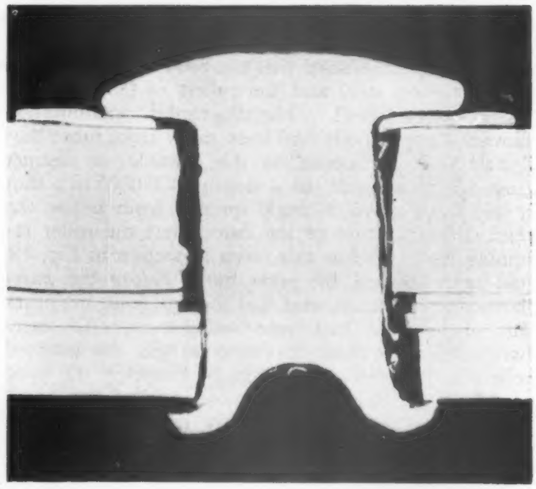


Fig. 24 x5

Section through assembly held with undersize rivet.

in Fig. 24, both the nature and the cause of some defective conditions are obvious; but please bear in mind that defects which are as serious as this may escape detection completely, if the simple precaution of examining sections when a job is first tooled up, and at intervals afterwards, is not observed.. In this instance, it was not until a number of assemblies had come loose in service that it was discovered, by examining sections, that too small a rivet was being used. When a rivet of correct size was used a reasonably good fit, as seen in Fig. 25, was obtained without modification to the tools, but it will be noticed that really complete filling of the hole has not been achieved, and that the tightness and security of the assembly depends not upon what, from the external appearance, looks like a sound head of quite adequate diameter and thickness but,

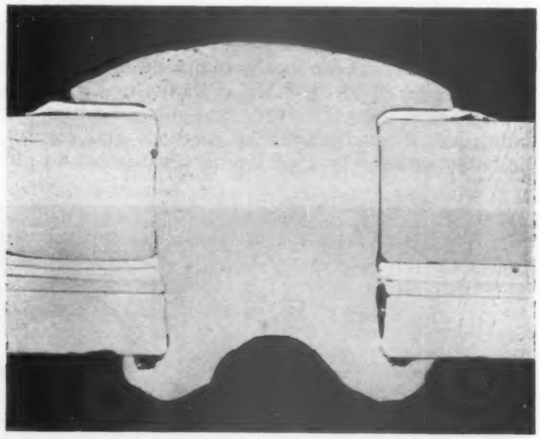


Fig. 25 x5

Section through assembly seen in Fig. 24 held with rivet of correct diameter but showing incomplete filling and thin rim on closed head.

in fact, upon a very thin rim of metal. Both these faults, which seem to be characteristic of the particular type of rivet illustrated, show how unwise it is to judge the behaviour of a rivet from the external appearance of the closed head.

These few examples will, I hope, serve to show how helpful the metallurgical microscope can be to the Production Engineer in all kinds of ways.

Unusual Problems

Every now and then the Production Engineer is faced with a really puzzling problem, which does not fall into any of the groups which the metallurgist usually has in mind while seeking the appropriate cause and remedy. Then, more than ever, he has to play the part of Sherlock Holmes. Two brief " case histories ", which can be called the *" The Case of the Masked Nitrider "* and *" The Case of the Missing Plate "*, will serve as examples of problems of this kind.

Continual trouble was at one time experienced owing to a certain component having, as can be seen in the photograph of it reproduced in Fig. 26, a patchy nitrided case with some areas completely

Fig. 26

Surface appearance of component exhibiting patchy nitriding.

free from case and others having one of very shallow depth. No positive indication of any of the usual causes, such as shielding in the nitriding box, dropping of molten tin from tin-coated articles placed higher in the box, the presence of grease, or the use of a wrong steel could be found in this particular instance. Going back further into the history of these parts it was discovered that, in order to minimise their tendency to rust between grinding and nitriding, they were ground with soda solution as a coolant. This dried on the surface, and the deposit was not completely removed by the trichlorethylene vapour degreasing operation which, quite rightly, was given to the parts immediately before they were loaded into the nitriding box. The introduction of a swill in hot water immediately after grinding, followed by a dip in a corrosion-inhibiting oil, cured the nitriding trouble and gave better temporary protection against rusting.

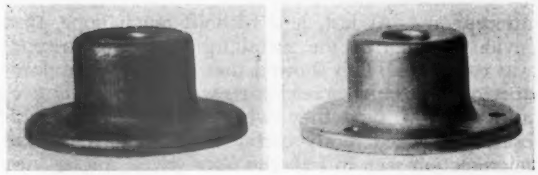


Fig. 27

Copper-brazed steel pressings after having been pickled prior to plating:
left—black deposit attributable to incorrect atmosphere in brazing furnace ;
right—clean, bright surface produced by correct furnace atmosphere.

In the second case, very great difficulty was suddenly experienced in plating the small copper-brazed steel assembly illustrated in Fig. 27, which previously had never given trouble. Quite naturally the plater was blamed, but a thorough check on both the cleaning and the plating processes failed to reveal any serious fault. Grieved and worried by the restrained but insistent remonstrances of the Production Engineer, whose flow line was stopped for want of some thousands of this particular part, the plater at last murmured something about the occurrence of a black deposit when these assemblies were being pickled, and the baby, complete with black deposit, was handed to the laboratory to hold.

It was found that instead of coming out of the pickling vat with a bright appearance such as that seen on the normal and satisfactory component illustrated on the right of Fig. 27, the troublesome ones emerged covered with a thin film of carbon sludge as seen on the left of this picture. The problem then was, how did the carbon get there, for chemical analysis showed that the components had been made from the specified low-carbon steel and not, in error, from a high-carbon steel. No carburising operation was given at any stage to any of the parts used. The assembled parts were copper-brazed together in a continuous controlled atmosphere furnace, from which they emerged with that silvery-white surface which is generally regarded as being indicative of a reducing, and hence decarburising rather than carburising, furnace

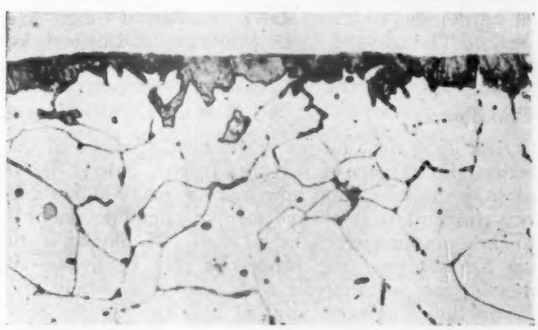


Fig. 28

Microsection through unsatisfactory pressing from Fig. 27 showing carburised surface layer.

atmosphere. At last, and without much hope, that invaluable tool of the metallurgist, the microscope, was called in. This showed that the surface appearance of the copper-brazed parts was utterly deceptive, and that in fact they were emerging from the brazing furnace thinly carburised, as shown in the microsection seen in Fig. 28. Analysis of the furnace atmosphere enabled the appropriate adjustments to be made, the parts emerged free from carburisation as seen here, no carbon sludge formed during subsequent pickling, the plater smiled again, the Production Engineer restarted his assembly line, and the metallurgist vowed to discard for ever the old belief that only a reducing atmosphere can produce a silvery surface on steel.

Explaining to Operators

If the various troubles which the Production Engineer has to overcome are classified, it will be found that although many have their origin in materials, processes or machines, a substantial proportion is directly attributable to carelessness or disobedience on the part of operators, or even foremen. Although the temptations which seem to be inseparable from piecework systems of working will always have to be resisted, it is my belief that many lapses are due more to a lack of imagination than to more culpable causes or attitudes of mind.

If the operators themselves are occasionally brought into the laboratory and shown the result of their misdeeds under what to them are probably not unimpressive surroundings, the change in the quality of their workmanship is often astonishing. When operators really understand that harsh grinding can produce not only large cracks, which can be seen, but also small cracks and local softening which *cannot* be seen by normal methods of inspection; that this condition is likely to cause a highly-stressed component to fail; and that the failure of a vital part may well mean the loss of a single-engined aircraft; if they can be made really to understand this, the great majority of operators will do as they are asked to do.

Admittedly, harsh grinding is a very simple fault to explain, but equally good results can be achieved with operators engaged on carburising, many forms of hardening, welding and a number of other processes. The method is one which could, I believe, be used much more widely with great advantage.

Conclusion

Any good metallurgist is continually aware of the serious limitations of his knowledge ; indeed, he is often dismayed to find how little he really knows and how difficult it is always to give adequate answers to the questions which he is asked. If, having spent his *life* studying the properties and behaviour of metals, the metallurgist feels like this, surely the Production Engineer, who at best can devote only a small fraction of his time to the study of metals, need not feel that it is derogatory to seek help from those who have more knowledge concerning this specialised subject than he has. Perhaps one of the reasons why this help is not sought more often is that the Production Engineer does not always realise how useful the help of the metallurgist could be, not only when actual trouble occurs in the factory, for then it is often too late to make those changes which are really needed, but also when the production of any part or assembly is being planned. Indeed, it is during the pre-production stage that the metallurgist's advice concerning both materials and processes can usually be most far reaching and effective.

In the time available it has been possible to explore only a small part of the field suggested by the title of this lecture; but if what has been said has reminded you of at least some of the obvious ways in which the Production Engineer can usefully employ the services of the metallurgist and if, perchance, it has suggested a few ways which had not previously occurred to you, it will have achieved its object. To those whose particular interests have not been mentioned, and to those who may feel that I have placed too wide an interpretation on the term "Production Engineer", I can only apologise.

It is my strong conviction that much benefit would result if the Production Engineer and the metallurgist, and quite often the designer of a product too, got together more closely, and much more often, than usually happens now. In this way, faults and difficulties obvious to one but unappreciated by the others could be discussed freely, and the best compromise, for nearly always it will have to be a compromise, decided upon. This is the thought I want to leave with you, and I do ask that you will not dismiss it casually as a biased metallurgical opinion. Metallurgical it certainly is, and biased it may well be; but the belief is one which has grown steadily during twenty-five years of factory experience dealing continually with the theme of this paper.

Acknowledgments

Very nearly all the photographs which I have used to illustrate this paper have been taken in the various laboratories of Joseph Lucas Industries Ltd. I express my thanks to them for permission to use these pictures and also much of the material on which this paper is based, and to those who by taking photographs and making slides have helped me in its preparation.

References

1. "Difficulties and Developments in Deep Drawing and Pressing." Published in the Journal of the Institution of Production Engineers, March, 1946.

2. "Increased Production, Reduced Costs, Through A Better Understanding of the Machining Process and Control of Materials, Tools, Machines." (Machinery Research Program sponsored by U.S.A.F.). Published by The Curtiss-Wright Corporation, Woodbridge, New Jersey, U.S.A.

COMMENT

The following comments on Dr. Jevons' paper have been received :

From : Mr. K. J. B. WOLFE, M.I.Prod.E., Chief Metallurgist, B.S.A. Tools Group, Birmingham.

Dr. Jevons should be congratulated and commended on this paper, because it brings into focus in a very clear manner several of the ways in which the metallurgist can be of use to the Production Engineer. Dr. Jevons has gone straight to the point in his third paragraph when he stresses the very great benefit that would result if the designer, the Production Engineer and the metallurgist were in much closer collaboration than they often are at the moment. In fact, the writer would go so far as to say that this is a cry from the heart and Dr. Jevons, as one of our leading industrial metallurgists, has repeated this thesis for very many years. It is to be hoped that the Production Engineer will carefully read this paragraph, ponder on it and then act on the excellent advice given.

The writer is in complete agreement with what Dr. Jevons has said and in certain ways would go even further. In addition to the subjects mentioned, the metallurgist can also give very valuable advice on tools and tooling for production and when very often 80% of the price of an article is the cost of its machining operations, it can be readily realised that a slight reduction in cost in any one of the metal shaping operations can show a very marked reduction in the finished cost of the article when overheads have been calculated.

The shortage of alloys in constructional type steels has also given rise to certain difficulties in manufacture which only metallurgists can help in successfully overcoming. At the moment, for most production processes the original BSI 970 alloy case hardening steel specifications, i.e. En.33—39 are no longer available for general use, and new type specifications have been introduced which depend on the effect of additions of small quantities of at least four alloying elements, i.e. manganese, nickel, chromium and molybdenum. Whilst satisfactory mechanical properties can be obtained from all of these steels, the more subtle type of difficulty such as thermal distortion during heat treatment, especially in such complicated parts as bevel gears, really needs the services of a metallurgist before really satisfactory flow production can be obtained from this type of material.

Returning to Dr. Jevons' paper, the sections covering "Cracks, Their Origin and Danger," "Grinding" and "The Influence of Microstructure on Machinability" should really be studied, as they bring to light subjects that are normally little known by the Production Engineer. The section on explaining to operators is also of the highest importance. Operator psychology is a subject of the greatest importance to the Production Engineer, due to the fact that unless the operator will really co-operate to his utmost ability, any improvement initiated either by Production Engineer, designer or metallurgist can be completely nullified.

From: Mr. PHILIP NEILL, M.I.Prod.E., Director, James Neill & Co. (Sheffield) Ltd., Sheffield.

How often in the medical world do we hear of the general practitioner or the patient requiring a second opinion ? They have called in a specialist! But the medical world only have two models to deal with, with many parts common to both. Surely there is far more justification for the Production Engineer, with his multiplicity of models, materials and methods, to require expert guidance and in matters internal the metallurgist is certainly his most competent adviser.

If, through the reading of this paper, Dr. Jevons has succeeded in bringing the Production Engineer and the metallurgist into closer working arrangements, then he has done a service in the field of applied science. Whilst, on his own admission, he has not attempted on this occasion to deal with many of the more familiar forms of co-operation such as heat treatment, welding and plating, etc., he has undoubtedly covered many other aspects of this wide subject in a most admirable manner.

As regards successful co-operation between the Production Engineer and the metallurgist, I think it is necessary to stress the need for more mutual trust between the two parties and to remember that a little knowledge can be a dangerous thing. In this connection, it must be appreciated that the metallurgist has an insight into the constitution of alloy systems and structures which rarely come within the sphere of those normally concerned with matters of a more mechanical nature. Furthermore, in building up a satisfactory working arrangement between these two partners, it must be remembered that the metallurgist is sometimes at a disadvantage in providing concrete evidence for the theories which experience and training teaches him to be correct.

A point on which possibly more emphasis could be laid is the advantage to be gained by the closest possible metallurgical examination of materials from which repetition components are being made. Sound material considerably simplifies production, but constant checks are necessary and the services of the metallurgist can often eliminate or detect, before expensive machining is carried out, troubles which do arise from time to time from such factors as de-

carburisation and segregation. The more elaborate the components which are being manufactured or the more expensive the materials from which they are made, the more is there justification for close metallurgical examination.

In connection with Dr. Jevons' observations on the study of specifications, I would add that much help can also be provided by an experienced metallurgist in the selection and provision of concise information, as opposed to the often long and complicated information in text books, which so rarely apply to one's own particular problems.

As regards the control of production, I note that Dr. Jevons has made no reference to the assistance which the metallurgist can give to the Production Engineer in the selection of suitable equipment for such matters as temperature control and the wider application of instruments, and I know from experience that in most organisations where a metallurgist is available, it is in this direction that the Production Engineer usually finds the most up-to-date information and the best guidance.

But when attempting to avoid trouble or endeavouring to get out of a tight corner, where are these metallurgists to be found at short notice ? Writing this from Sheffield, I would merely add that we are surrounded by them—there is no difficulty in getting an opinion at almost any time, but it is obviously not so easy in districts where metallurgists find it more difficult to survive. The answer almost invariably lies in the laboratories of your material supplier and it is to be hoped that the paper which Dr. Jevons has presented will greatly encourage those who do not enjoy the facilities of a metallurgist on their own staff, to call for expert guidance from those normally responsible for providing the raw materials which form the basis of our production programmes.

From : Mr. EDWARD LLOYD, A.I.M., A.C.T. (Birm.) (Associate Editor, " Sheet Metal Industries ").

Dr. Jevons is to be congratulated on the presentation of a paper, the subject matter of which should be of great assistance to the Production Engineer. It is perhaps unfortunate, however, that the *need* for a paper of this type exists, as many of the defects and difficulties mentioned by the author, it would be thought, are a matter of plain commonsense. In any case, they would never arise if the Production Engineer had long ago realised the value of co-operation with the metallurgist, and had formed the habit of consulting him when a new product was in course of development. It is indeed to be regretted that in general the Production Engineer (using the term, of course, in the widest sense), seldom calls in or consults the metallurgist until it is too late to introduce a remedy as distinct from a palliative. That this state of affairs *does* exist can be confirmed by the writer of these comments, who spent fourteen years in the Development and Research Department of a large metal producing organisation, dealing with the very problems mentioned by Dr. Jevons, the majority of them after production had commenced.

What is the reason for this attitude on the part of the Production Engineer ? Is it due to antagonism from the fear of being " blinded with science," or is it due to the more likely reason of ignorance of the nature and extent of the help that could be given for the asking ? Whatever the reason, there is no necessity for its existence. Consultation and co-operation can only result in benefit to all concerned.

Co-operation between designer, Production Engineer and metallurgist should begin *while a new component is still on the drawing board.* It is only by adopting this procedure that unsuitable materials, processes and methods of manufacture can be avoided, manufacturing hazards foreseen and eliminated and, if necessary, even the shape of the article modified in non-essential details to assist production. Increased productivity cannot be obtained solely by calling for harder work, or by the installation of new machines or equipment. Correct design for the materials being used or *vice versa* is probably more important.

That there is a *need* for co-operation is amply borne out by the large industrial organisations, who find it advantageous to spend large amounts of money on extensive laboratories and their staff. If, therefore, these same large organisations acknowledge the existence of this need, is it any less likely that it does not obtain as far as small firms are concerned ? The answer to this, of course, is no, but the smaller firms would not be able to maintain a laboratory or, in many cases, even a metallurgist as part of their normal activities. This difficulty is not, however, insurmountable. For instance a firm could use the services of a consulting metallurgist when required, or a group of firms in an area could jointly employ a full-time metallurgist. Many of the metal-producing firms have extensive laboratories and help from them for users of these company's products is readily given. In addition, there are the development associations, such as the Copper Development Association and the Aluminium Development Association, whose advice and help is always available, and finally the research associations, such as the British Iron and Steel Research Association, the Production Engineering Research Association, the British Welding Research Association, the British Non-Ferrous Metals Research Association, membership of which entails only a comparatively small capital outlay for the many and valuable services available.

It should be apparent, therefore, from Dr. Jevons' paper that co-operation between designer, Production Engineer and metallurgist, is an obvious, and essential, rung in the ladder to increased productivity and not only increased productivity, but also "trouble-free " productivity, and initiated at the proper time in the production of a new product can give savings in time, labour, and above all, materials.

NOTE : Comment is invited on papers published in the Journal. Contributions, which should be brief and to the point, should be addressed to the Editor, 36, Portman Square, London, W.1.

MODERN ADHESIVES

by R. A. JOHNSON.

ABSTRACTED FROM A PAPER PRESENTED TO THE WOLVERHAMPTON SECTION OF THE INSTITUTION OF PRODUCTION ENGINEERS, 4th APRIL, 1951.

THE first satisfactory metal adhesive was developed by Aero Research Ltd., in the early 1940's and possesses the name of 'Redux'. This was, until 1952, the only metal adhesive which was approved for use on the load bearing structures of aircraft and has been used very extensively for this and other purposes.

The advantages of using adhesives compared with other means of joining materials are as follows: the first consideration is that of strength and in this respect it can be said that for thin gauge metals of the order of 18 s.w.g. or less, there is a definite strength advantage when compared with riveting. A simple 1″ wide lap joint of ½″ overlap when bonded with 'Redux', will have a failing load of approximately 2,500 lbs. in shear, whereas a comparable joint with one ⅛″ duralumin rivet, corresponding to riveting at 1″ pitch, will fail at about 500 lbs. In addition, the fact that the whole of the joint face is in intimate contact prevents stress concentration being set up around focal points such as rivets or bolts. It has been established, in tests carried out by various aircraft manufacturers, that similar structures can show a strength advantage, when bonded, of up to 40% in excess of the strength of the riveted structure.

It may be argued that welding is preferable to riveting and that in such cases, the strength of the welded joint will be the strength of the materials being joined. This is partially true but there are several disadvantages when welding light alloys. If it is desired to use a high strength alloy, it is inevitable that where this is welded the metal will be reduced to the "as cast" condition with a subsequent drop in strength. There is therefore no advantage to be obtained by the use of high strength alloys. There are at least two other difficulties with welding, the first being that where fluxes are necessary, they are invariably of a corrosive nature and the second is, that weld metal contracts during solidification an average amount of 5%, dependent upon the composition of the melt. This sets up stresses which may result in cracks either in the weld or adjacent to it.

Appearance of a joint is usually another important consideration, especially to the aircraft designer. Now that aircraft are reaching speeds equal to and beyond that of sound, the surface of the skins of aircraft is of great importance. It has been ascertained that even a well finished countersunk rivet head has a very disturbing influence on air flow at high speeds. The only way to achieve smooth skins is by the use of bonding techniques and this has been well demonstrated by The de Havilland Aircraft Company with the "Dove", "Heron" and "Comet" aircraft. In addition to the external smoothness of the skin, it is desirable to dispense with rivets wherever possible, as most aircraft today are pressurised internally and every rivet hole is a potential leak. One further design point is that due to the absence of rivet holes in wing skins, the fuel tanks can be an integral part of the structure and not separate components. Apart from the improved appearance and performance of bonded structures, there is of course a saving of weight.

The final consideration is that of cost. The time taken to drill all the rivet holes in two or more components, plus the time required to fill up these holes with rivets, is quite considerable. When bonding, however, no matter how large the components the bonding time remains constant, the limitation being imposed by the size of equipment available. Against this, there is a larger outlay for tools for bonding large areas. In spite of this, the cost of producing bonded components for the "Dove" aircraft was only about 60% of the equivalent cost of riveted components.

Methods of Bonding

There is another adhesive which will satisfactorily bond metals or other non-porous materials and that is 'Araldite'. This was discovered by the Swiss, but is also being manufactured and developed in this country. This adhesive was approved by the Ministry of Supply in 1952.

The most important operation in the bonding technique is undoubtedly the first one—that of degreasing. Unless this is carried out correctly and efficiently, it is impossible for the bonding to be successful. Usually a trichlorethylene vapour bath is recommended for this operation, but there are certain proprietary degreasing materials which may also be used with success. After degreasing, which is common to both 'Redux' and 'Araldite', the next stage is that of cleaning the metal. This should be done in order to remove any rust or in the case of light alloys, oxide film which may be loosely attached to the surface. It may be done mechanically by shot blasting or abrading, or may be done chemically with an etching solution. If, however, the oxide film is deposited by anodising, this is satisfactory.

From this point the technique of applying the adhesive varies. 'Redux' consists of two components, a liquid and a powder. The liquid is first applied by means of a brush, or other suitable method, to the area which is to be bonded. As soon as the liquid is applied, the whole component may be dipped into a tray containing the powder, or the powder may be sprinkled over the liquid-coated surface. It is then advisable to let this stand for

about half an hour in order to allow solvents to evaporate but, if desired, it can stand for up to three days before the joint is made. To complete the process the coated parts are brought together under a pressure of approximately 100 lbs per sq. in. and heated to 145°C. for 15-20 minutes. It is usually advisable to cool down to about 90°C. before removing the pressure, although in some cases this is not absolutely necessary.

'Araldite' differs from 'Redux' in that it is a gap-filling material and as such does not require pressure during the curing process. It differs from 'Redux' also in that there are no solvents to be evaporated and the adhesive may be applied and cured immediately. The most commonly used form of 'Araldite' is that known as Type 1, which is available either in the form of a powder or as a rod. The metal is first heated to 100°-120°C. and the powder or rod applied to it. On contact with the heated metal the adhesive flows and a film is deposited on the surface of the metal. This may then be allowed to cool or the parts to be bonded may be immediately joined together. It is then necessary to cure the resin which may be done at any temperature between 140°-240°C. Another method of applying 'Araldite' to large areas is by means of a Schori flame spray gun. Whilst the 'Araldite' is being cured, it is only necessary to apply sufficient pressure to prevent the component parts moving relative to one another. It is apparent that the application of adhesives is a relatively simple process which may be carried out by unskilled female labour.

"The Application and Selection of Electrical Equipment"

by N. PESTEREFF

(Synopsis of a paper presented to the Edinburgh Section of The Institution of Production Engineers, 21st November, 1951.

THE paper is divided into six sections which flow naturally one from the other. The sections are Introduction, Field of Application for Electricity, Evolution of a Rational Installation, Conditions of Operation, Power Supply Equipment and Conclusion.

In the introductory section, the general plan to be followed is set out as being an attempt to present a general solution to the problem of the selection and application of electrical equipment. The scope is delimited, covering the application of electricity only, consequently the selection of equipment for electric power generation, transmission and distribution is omitted. Also, all consideration of specialised applications such as electro-chemical and medical applications, welding as well as traction, are left out. Some of the limitations to the adoption of rational decisions by existing plant and type of staff selecting and operating equipment are considered, and some suggestions made to overcome these limitations. An example is given of the result of the selecting personnel not realising the risk being taken, and it is shown how easy it is for this to happen.

In the section dealing with the "Field of Application," the nature of electricity is compared to that of other sources of power and it is shown that the application of electricity to heating by direct degrading of electrical energy to heat is technically unsound ; the technically correct way of applying electricity to heating by making it drive a heat pump is explained and the theoretical advantage in the instance of plain space heating shown to be 30.3 to 1. The exceptions to the general rule of the non-use of electricity for heating in instances where heat is to be produced inside the body, and where infra red rays are used, are recorded. The efficiency of lighting sources is considered and the lowness of the existing standards shown. The limitations of discharge lighting are considered. A suggestion is made whereby lighting load can be removed from the peak demand in factory installations.

In the portion dealing with the evolution of rational installations covering the main theme of the paper, an attempt is made to work forward from fundamental conceptions. These are enunciated as, first, that while the design and manufacture of engineering equipment must necessarily be the work of specialists, it should be possible for the equipment to be operated by non-specialists; and, second, that it is wrong to impose multiplicity of functions on any piece of apparatus. The thesis is worked out in detail on the basis of medium power installations showing the selection of the type of motor, system of protection, type of control and distribution through the factory to which one is lead and the means of voltage control needed. The thesis is then shown to be generally applicable to fractional horse power drives and the application to larger installations is considered. This latter includes the question of the selection of voltage for larger machines and recommendations are made as to the type of switching equipment to be used with higher voltages.

In the section dealing with conditions of operation, questions of enclosure and ruggedness are considered. The means of meeting heavier duties are illustrated. The question of type of bearing to be used in motors and their lubrication is here treated.

In the section dealing with power supply equipment the question of magnetising current in A.C. supplies is considered, the need for a high power factor shown and some means of mitigating the difficulties mentioned. The possible economy in power by the use of back pressure steam installation is stressed and the feeding of the power into the system by induction generators shown.

In the conclusion, the reasonableness of the solution arrived at from the basic principles is stressed as being in line with current tendencies, and the hope expressed that the anticipated criticisms would enable specific points which of necessity must be skimped to be brought out and clarified.

The full papers are available to members on loan from the Hazleton Memorial Library

"PROBLEMS OF AIRCRAFT PRODUCTION"

SENIOR executives from every branch of the aircraft industry attended the Conference recently organised by the Southern Section of the Institution, to discuss "Problems of Aircraft Production." The Conference, which was held on 19th and 20th December last, took place at the University of Southampton, by kind permission of the Vice-Chancellor.

The programme was as follows:

FRIDAY, 19th DECEMBER, 1952

12.45 p.m. **Luncheon.**

Chairman :
F. C. Cooke, Esq., M.I.Prod.E.
Speakers :
Alderman Edwin Burrow,
Mayor of Southampton.
Mr. A. R. W. Low, C.B.E., D.S.O., M.P.,
Parliamentary Secretary, Ministry of Supply.

2.30-4.30 p.m. **Session I.**

"DESIGNING FOR PRODUCTION"
Chairman :
Professor E. J. Richards, M.A., B.Sc., F.R.Ae.S.
Speakers :
Dr. A. E. Russell, B.Sc., F.R.Ae.S., F.I.Ae.S.
Chief Designer, Bristol Aeroplane Co. Ltd.
R. W. Walker, Esq., F.R.Ae.S.
Chief Designer, Gloster Aircraft Co. Ltd.

5.0-7.0 p.m. **Session II.**

"PROTOTYPE TO PRODUCTION"
Chairman :
S. P. Woodley, Esq., M.B.E.
Speakers :
C. E. Fielding, Esq., O.B.E., A.F.R.Ae.S., M.I.Prod.E.
Works Director, A. V. Roe, Ltd.
H. Povey, Esq., A.F.R.Ae.S.
Works Director, de Havilland Aircraft Co. Ltd.

SATURDAY, 20th DECEMBER, 1952

10.0-11.30 a.m. **Session III.**

"THE IMPACT OF MODIFICATION ON PRODUCTION"
Chairman :
W. E. W. Petter, Esq., C.B.E., B.A., F.R.Ae.S.
Speakers :
T. Gilbertson, Esq., M.I.Prod.E.
Director and General Manager, Folland Aircraft Ltd.
H. S. Howat, Esq.
Assistant Director, Aircraft Production, Ministry of Supply.

12.0 noon-1.0 p.m. **Summing-up.**

Chairman :
F. C. Cooke, Esq., M.I.Prod.E.
Speaker :
Walter C. Puckey, Esq., M.I.Prod.E., F.I.I.A.
Deputy Controller of Supplies (Aircraft Production), Ministry of Supply.

Following the opening Luncheon, when the Mayor of Southampton welcomed the delegates, Mr. A. R. W. Low, C.B.E., D.S.O., M.P., Parliamentary Secretary to the Minister of Supply, said that it was appropriate for the Institution of Production Engineers to have organised the Conference at the present time, and in Southampton. Throughout the last few years and most of all during 1952, there had been a quickening of public interest in the production of British aircraft, both civil and service types. Southampton was a most appropriate place because so much—although not by any means all—of the production of the latest types of aircraft and of their components was carried on in the South of England, of which Southampton was such an important centre.

It was fitting, too, that the Conference was held at the University of Southampton. The interest shown in technological problems by many of the Universities would, no doubt, bear fruit in years to come.

The Ministry's Position

Mr. Low said that he had been posed a question —was the Ministry of Supply one of the problems of aircraft production ? When he had given his answer he hoped it would be agreed that whether

Photographed at the Luncheon are (left to right) Mr. Low; Mr. F. C. Cooke; the Mayor of Southampton; Air Marshal Sir Hugh Walmsley ; Professor D. G. James (Vice-Chancellor, Southampton University) ; Mr. R. W. Walker ; Mr. C. E. Fielding and Dr. A. E. Russell.

(*Courtesy of " Southern Daily Echo "*)

as customer or as a sponsoring department, the Ministry of Supply was a friend and not a problem-maker.

" We in the Ministry," continued Mr. Low, " come into your industry in two ways, as customer and as sponsoring department. In this second capacity we are both the guardian of the national interest in the aircraft industry, and the guardian of the aircraft firms' interest in national affairs. We are here to help and not to hinder—to guide and not to control.

" Let me first examine our position as a customer. It is generally accepted by all customers that customers are always ' right '—the Government is ' right ' to that extent as an aircraft customer. (I must not, of course, refer to political complexion when I say that it is right.) "

Referring to recent changes in the aircraft programme for defence, Mr. Low said that the production of the latest types was to go on as was intended, but the overall expansion of aircraft production for defence was not to be as great as originally planned. Nevertheless, the production of aircraft for the Services was to increase and, taking the whole of the industry, it was expected that some 10,000 additional workers would be engaged in aircraft production in twelve months' time.

The alteration of the programme made it all the more important to speed the production of Super-Priority types and generally to ensure punctual delivery under contracts.

The recent defence announcement on production of aircraft, besides affecting the R.A.F. and the Royal Navy, meant that more Service aircraft of the types in production would be released for other countries to buy. At the same time, the adjustment in defence programmes released more capacity and resources for the production of the latest types of civil aircraft.

Importance of Flexibility

Changes in planned orders and in programmes did not make the producers' job any easier for the time being. Changes in specification and in design at different times right up to clearance of the aircraft by the Controller were further trials. Although considerable trouble was taken to avoid chops and changes, it was impossible to avoid them altogether, and consequently production plans must have great flexibility ; that was, no doubt, one of the reasons why it was so very rare for a forecast of deliveries of new types of aircraft to be accurate. The mathematical precision—almost 100 per cent.—with which experts could state exactly the performance of an aircraft designed according to certain specifications contrasted—in Mr. Low's short experience—remarkably and strangely with the mathematical imprecision of production forecasting.

He had seen enough to know that the modern aircraft was one of the most complex, intricate and difficult things to build. It also cost a great deal of money. It was so good because there was so much skill in its design and in its production, and for this very reason it seldom remained exactly the same design for very long.

Other difficulties had been made greater during the past two years because of the shortage of raw materials, capacity, and skilled labour in relation to the pressing demands upon them. That was now easing. Super-Priority had helped in special cases and did no harm to others. Nevertheless, said Mr. Low, he would be interested to hear the results of any discussion on how to secure improvements.

He had mentioned programming difficulties. Of course they mattered as much to the Government as to any customer. They mattered especially to the R.A.F. and Royal Navy, because of their effect on manpower planning. But they were only a part, or rather a sympton, of other difficulties of early production. The further science advanced, the more complex the equipment that was designed, so the longer the period of industrial gestation from the drawing board to full production. Nature did not suffer in this way ; the human being came to life more quickly than the larger and less scientific elephant.

Maintaining the Lead

The aircraft industry as a whole had a reputation for *quality*, but had not a reputation for *early production*. Those were facts—not personal comments. In competition with the world, the British aircraft industry had now a clear lead in prototypes, military and civil. That lead had recently been translated in some spheres into production and in aircraft flying in reasonable numbers. Everyone wanted to see that lead maintained. No one was a Jeremiah, and none complacent, but how many were fully satisfied that even with the full maintenance of the British lead in research, it would be maintained in future production ?

The wisdom and skill of the Production Engineer was only one of the essentials—but all those other essentials to which the Government gave much thought affected Production Engineers..

The Ministry as Sponsor

Turning to the Ministry of Supply's position as a sponsoring department, Mr. Low expressed the wish that the public understood better the problem to be faced, and the undoubted efficiency of the firms involved. It was quite clear from the public reaction to statements on possible delivery dates of new types of aircraft (for example, the larger Comet) that too many people, consciously or subconsciously, imagined that the production of a new aeroplane could be achieved, as it were, by turning on a tap. Or they thought of a new aircraft like a new piece of household equipment—to be bought off the shelf.

Some people went further and imagined that the aircraft industry should be able to switch production from one type to another, by turning off one tap in the hope that a different tap could be turned on immediately thereafter, to gush forth glistening aircraft of a design first settled the day before. One of the most respected officials in the Ministry of Supply claimed to have grown grey in persuading succeeding generations of R.N. and R.A.F. officers —and, he adds, succeeding generations of Ministers —that it was not possible either to save money or get a succession of good aeroplanes that way. The first essential was a wide understanding of production problems.

The second essential was that the customers and the producers had to arrange their affairs so that there was a steady level of production, avoiding if possible the high peaks and the low troughs. In this way, the recent adjustment to the defence programme might be more healthy for the aircraft industry and more helpful to its future than many had yet acknowledged.

Stability in the Industry

The third essential was similar to the second—a measure of stability in the industry. Without it, recruitment of new skill would be almost impossible, and it would be impossible to maintain the skilled force built up. With it, apprentice shops and training schools would be easily filled, and those joining the industry would remain. The glamour, the excitement and the pleasant conditions associated with all branches of aircraft production would see to that. It was very important for all to know that the adjusted defence programme required that 10,000 more workers would be recruited to the industry in twelve months' time.

But there was more reason than the defence programme to look with a certain confidence to the future. There were brighter prospects for civil aircraft production than ever before, prospects provided in the main by the enterprise of firms, but in differing ways contributed to by the research effort and general co-operation of the Ministry of Supply.

Competition there would be from others overseas, but there was no reason today to fear competition in quality—nor, at present, competition in cost. The danger was competition in date of delivery—a danger by no means confined to the aircraft industry.

Facing the Challenge

In conclusion, Mr. Low said :

" This is a problem about which we have been doing a lot of thinking. But ultimately it is your problem, and like all problems in which time plays the leading part, it is urgent. The opportunity once lost may never return.

" You, I am sure, have been thinking about it. Some of our friends and some would-be customers in the U.S.A. gaily talk as if you cannot solve it, and as if that problem had been solved in the U.S.A. They are wrong.

" I am greatly interested in the steps that Mr. Puckey has inspired in the Ministry of Supply to conduct research into and to develop production methods. This Conference will, I have no doubt, make a contribution. Your industry faced and overcame the challenge of time before, when in 1940 it helped to save Britain. You and your predecessors played a part equalled by few others, in the years

of growing strength—1941/1945. Now, again, the challenge is—can you make the best of the skill, the workmanship and the scientific and technical lead of Britain *in time* ?

"It is for you to meet that challenge. It is for us to do what we can to help you and provide the conditions in which you can be successful. For defence and exports—and as you know, the Chancellor has just called for a 20 per cent. increase —we look to you. In the reign of Elizabeth I, the ships of Britain filled the oceans. In the reign of Elizabeth II, let the aircraft of Britain fill the skies. Those ships helped to give the world peace and growing trade. Your aircraft will do likewise."

The two papers given in Session I of the Conference appear on pages 86/104. A report of the Discussion following these papers, together with the two papers presented in Session II, will be published in the March issue of the Journal. The April issue will contain a report of the discussion in Session II, Session III and the Summing-up.

DESIGNING FOR PRODUCTION

PART 1

by Dr. A. E. RUSSELL, B.Sc., F.R.Ae.S., F.I.Ae.S.

Dr. A. E. Russell

Dr. Russell, who was born and educated in the West Country, joined The Bristol Aeroplane Company in 1926. He was subsequently appointed Chief Technician, Deputy Chief Designer, and, in 1951, Director and Chief Designer, which is his present appointment. He is also a Director of Rotol, Limited.

In 1949, Dr. Russell was invited to present the 13th Wright Brothers Memorial Lecture in Washington, U.S.A., and in 1951 he was awarded the British Gold Medal by the Council of the Royal Aeronautical Society for practical achievement in aircraft design. In the same year, he was awarded the Honorary Degree of Doctor of Science at the University of Bristol.

THERE are many factors that must be taken into account during the course of the design of a new aircraft. Some are related to the natural laws. In this category it is possible, by calculation and/or experiment, to predict behaviour in the fields of aerodynamics, aero-elasticity and structures. Later, it is possible to check the results achieved in the finished product. Other laws, this time man-made, must be observed in order to qualify for a certificate of airworthiness. Again, results are carefully measured and documented for the purpose of controlling operating standards in service.

It would, however, be relatively simple to comply with both such sets of laws, while at the same time offering unexacting problems to Production Engineers, but for the dominating demand for achieving operating efficiency. Quite small sacrifices in this last direction, in the sole interests of simplicity, may so penalise the competitive value of an aircraft as to present the market to a competitor and so nullify the whole project.

So I would like to add a conditioning clause to the title of this talk, so that it should now be understood to read "Design for Production for Sale."

In the interests of better focus, I propose to limit my review to medium and large civil aeroplanes.

Testing of Civil Aircraft

Civil aeroplanes are sold in the cold light of day with all performances freely quoted in the technical press. Before they are sold, potential operators go to great lengths to reassure themselves that the type they buy will be safe, have a long life, suit the specific stages of their particular airline and will be economic in operation. A manufacturer can be certain that if there are defects in the airframe, power plants or equipment, they will inevitably come to light. He must therefore take all possible steps to avoid and eliminate trouble in the least embarrassing stage, that is to say, in the earliest possible days. Presently I will expand on this theme, but for the time being, leave it with a point of emphasis on the need for extensive testing before production is committed. This procedure is costly and time-consuming, but not so expensive as later modifications and a bad reputation. It is indeed an assurance to counter grave risks, and an essential contribution towards breeding confidence.

The Export Prospects

You have heard and read a great deal about the future of civil aircraft as a major export. The size of the potential market puts our endeavours into their proper perspective.

There are some 900 4-engined aircraft and about twice that number of twin-engined aircraft operating on the world's major air routes, which cover all conditions of climate and geography. This year the combined airlines will carry 50 million passengers, 600 million ton miles of cargo and 200 million ton miles of mail, together earning about £800,000,000 revenue. These figures are increasing year by year.

It is a reasonable assumption that most of these aircraft will be replaced over the next ten years and their total value certainly exceeds £1,000,000,000. i.e. a sales potential averaging about £100,000,000 a year. To this must be added a considerable sum for spares. The American aircraft industry has for a long time held this market and is making the most determined efforts to retain it.

It would be idle to underrate American skill both in making fine aircraft and in selling them. If Britain is to make appreciable inroads into what has become virtually American engineering territory, our aircraft must reach superlative quality and be produced in sufficient numbers while order books are still open. To this end, it is essential that design and manufacturing teams reach an understanding, so as to exploit any and all advantages at our disposal.

In this direction each side must recognise the limits of manoeuvre available to the other. On the one hand, design cannot depart from those technical standards necessary to attain the required performance and, on the other hand, production cannot create unlimited resources. Lest this appraisal should appear to encourage an emphasis on limitations, possibly leading to appeasement, I must hasten to add that it is important to verify that such limitations are fundamental and not artificial.

The Root of All Problems

Now the root of all problems in design and manufacture arises from the insistent call for low structure weight and high surface finish. A short illustration of these basic premises will give perspective to our scope for profitable exploration.

Dealing firstly with weight, the allowable maximum operating weight of an aeroplane is that at which it just satisfies certain performance standards laid down by the licensing authority. The fully furnished and equipped empty weight can be assumed to be 50% of the gross weight. At some range the quantity of fuel that must be carried will be 30%, in which case the payload will be 20%. Suppose a payload of 30,000 lb. is specified, it follows for the values assumed, that the appropriate aeroplane would have a gross weight of 150,000 lb.

Now assume that the design had been less efficient and the empty weight 52% instead of 50%. At the same range the payload would be reduced to 18%, so that in order to carry the same payload as before the gross weight would have to be increased to 167,000 lb., demanding a corresponding proportional increase of engine power to give the same performance.

Thus, in this example, leaving 4% more material on each part, i.e. about 2% on dimensions, would increase the empty weight from 75,000 lb. to 87,000 lb. It is unlikely that the average overall manufacturing cost per unit weight would be materially reduced by so small a change, so that the total cost of an aircraft at about £9/lb. would increase by over £100,000 (Fig. 1).

TOTAL WEIGHT OF AIRCRAFT - W

	EXAMPLE 1	EXAMPLE 2	RATIO $\frac{2}{1}$
BASIC EMPTY WEIGHT	0·50W	0·52W	1·04
FUEL LOAD	0·30W	0·30W	1·0
PAYLOAD	0·20W	0·18W	0·90
	1·00W	1·00W	
ASSUMED PAYLOAD	30,000 lb.	30,000 lb.	1·0
TOTAL WEIGHT W	150,000 lb.	167,000 lb.	1·11
EMPTY WEIGHT	75,000 lb.	87,000 lb.	1·16

Fig. 1

It is not only this addition to the first cost that would repel possible customers, but also the thought of having to bear increased landing and fuel charges throughout the life of the aeroplane.

Another approach to this question of weight can be made from the operator's end. A civil aeroplane can be assumed to have an average block speed of x m.p.h., an annual utilisation of y hours and a service life of z years. This gives a total distance travelled of $x.\ y.\ z.$, which can work out to about 10 million miles.

Now assume that the payload could be increased so that one extra passenger could be carried, then at 3d/mile fare the additional potential revenue amounts to something of the order of £100,000. The weight of a passenger and his luggage, together with his share of general furnishings and equipment, is about 500 lb. This suggests a value of £200 for one pound weight.

The argument, of course, ignores the occasions on which the traffic offering is less than the capacity available and so is akin to working out annual rainfall by measuring the quantity of water collected during a thunderstorm, without taking into account the durations and frequencies of thunderstorms. Airline operators are, however, notoriously pessimistic folk and rarely go about without carrying an umbrella.

Incidentally, if it is assumed that on 25% of all operations, all available seats can be sold, the value of a unit of weight to an operator is almost the same as that derived by my first assessment, but whatever the actual value may be it is certainly large, and it is safe to declare that parasitic weight cannot be excused.

Parasite Drag

Parasite drag may be defined as drag arising from departure from the ideal streamline form. In his endeavour to minimise such losses, the designer presents to the Production Engineer problems related to surfaces embodying double curvature, flush rivets, butt joints and svelt contours.

Excess drag has a double impact on operating efficiency. I have already indicated that certain performance standards limit the maximum weight at which an aeroplane is authorised to fly. Certain of these tests apply to minimum permissible rates of climb after an engine has failed. In this condition, the remaining power is used partly to overcome drag and partly to supply the energy for the climb. It is obvious that a transfer from power required for drag to power available for climb will enable the aeroplane to satisfy the requirements at a greater all-up weight.

The endeavour in design is to balance weight reduction against drag reduction, so as to obtain the best all-up weight for the engine power available.

Excess drag has a more obvious influence in normal cruising conditions, resulting as it does in greater fuel consumption, shorter range and decreased speeds. Each of these effects appear in the analysis of operating costs, so that an initial increment has an accumulating and adverse bearing on economy.

This account has, I hope, been sufficient to dispose of any suggestion that airline operators can be expected to have any sympathy for unsophisticated techniques in design and production.

Importance of Planning Ahead

With the prospect of producing what is inevitably a refined and complex engineering machine, it is important that we employ wisdom and foresight in our procedures. These must be based on imaginative but rational lines, aggressive but enlightened principles.

Now the circumstances in which a Production Engineer operates fall roughly into two stages. The first is the prototype stage, at which time he has some scope in influencing design, more especially as regards the breakdown of components and sub-assemblies; but at this stage he must limit his manufacturing liabilities in case of alterations subsequently found to be necessary as the result of ground or flight tests. The second is the production stage, by which time he has much reduced freedom to suggest design changes, but far greater control over the manufacturing cycle.

I am taking it as axiomatic that, today, there is

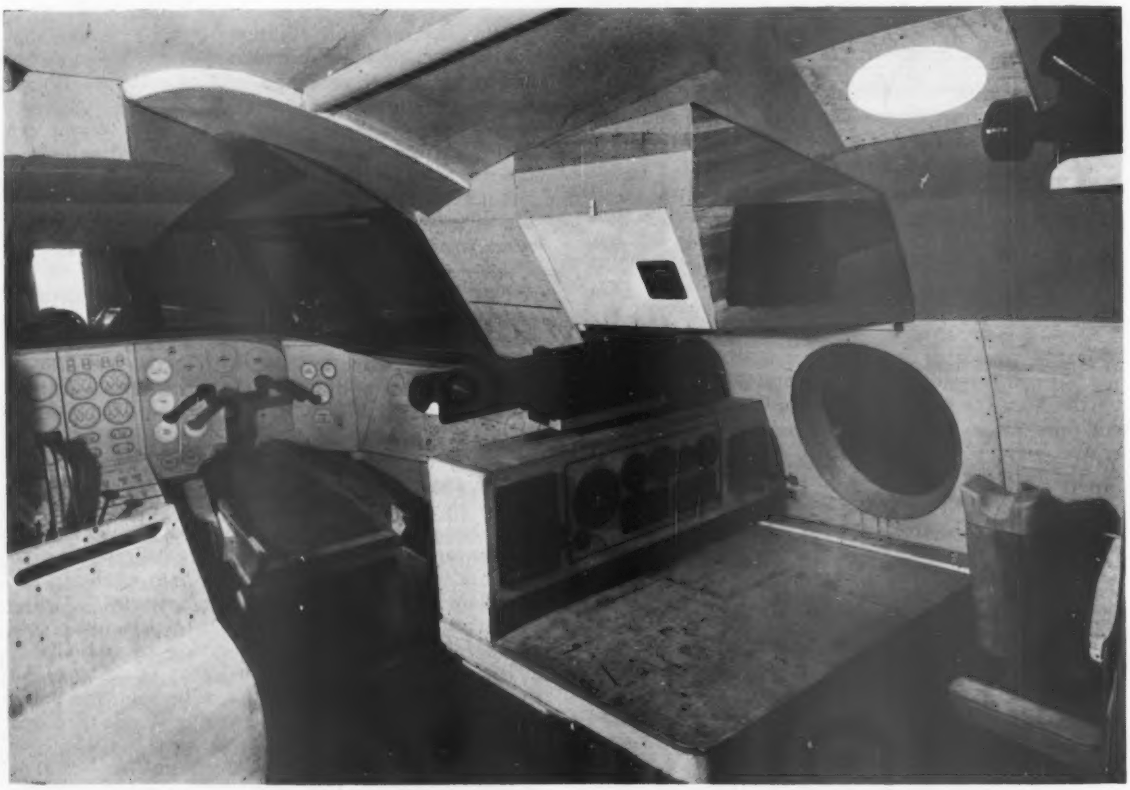


Fig. 2

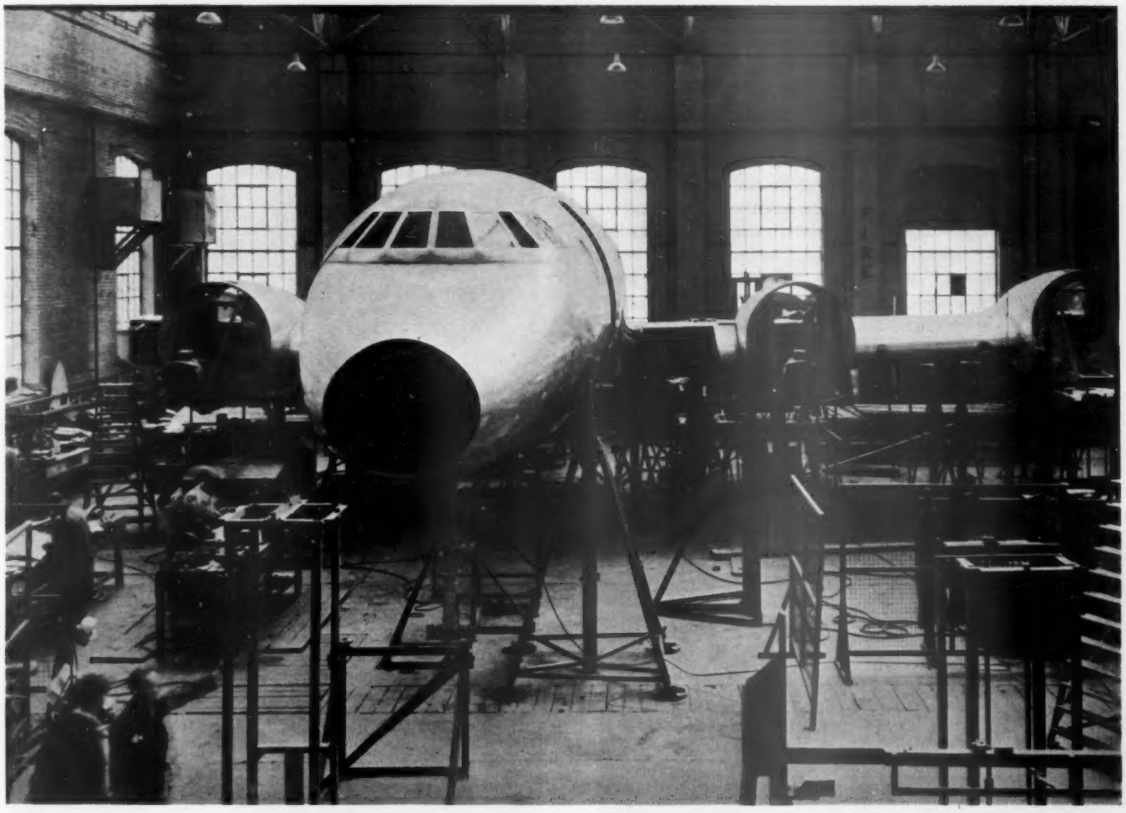


Fig. 3

no conceivable situation when time would permit of a significant amount of redrawing after the prototype trials, with the object of productionising the design. The trend is towards increased overlap between the prototype stage and production and, consequently, the risks of modification are greatly increased.

There have been cases where provision against this danger has not been satisfactory, with the result that the modifications that have had to be introduced, have caused major setbacks to production. So before passing on to examine alternative methods of fabrication, we must first discuss ways of proving the soundness of the design at the earliest possible stage. Although many of the tests that I now propose to outline are undertaken as normal practice, their mention on this occasion is justified, as their purpose is not to bolster up the courage of some nervous technician, but to eliminate more serious trouble.

The First Stages

One of the earliest steps taken in a new design is the testing of models in wind tunnels. This work extends continuously during the design and development period. It is directed towards establishing, among other things, the correct dihedral, flap shape, tail surface areas and flying qualities. Such work is as important, though perhaps not so spectacular, as the mechanical testing of structural specimens to destruction. Both programmes are essential to confirm the integrity of the design, and to avoid suspense, the construction of major structural components must have priority over prototype airframes.

It is also customary to build a fairly elaborate full scale wooden mock-up of the aircraft (Fig. 2). This mock-up illustrates in three dimensions, as no drawing can, those features whose arrangement and location defy precise definition, a condition conducive to strong views by experts. Eventually a truce is called and drawings are issued for manufacture—until a new customer arrives.

Thus far, I have outlined the usual precautionary measures. I now want to make a case for a recent innovation, the functional mock-up (Fig 3). This is virtually another prototype having those limbs or sections, not carrying important services, amputated. The purpose of a functional mock-up is to develop the systems, the electrics, hydraulics, pneumatics, in as near their correct environment as is possible on a ground test rig. Such development can include not only check tests on their functioning, but also the 'cleaning up' of their installation. There is no

need for me to tell you that these systems are complex, and that if not skilfully arranged, the miles of pipes and cables can resemble an unravelled woollen jumper.

We can take the hydraulic system as an example of what can be achieved on a functional mock-up. Firstly, those units, whose position is dictated by their purpose can be installed. The remaining parts of the system are fitted in the best manner that can be evolved on the drawing board and/or wooden mock-up.

Then a team, made up of engineers with appropriate experience in design, service operation including maintenance, and production, is given the job of making a critical survey of the installation. They should be able to eliminate faulty mountings, and tidy up the pipe runs and their supports, while bearing in mind general and detail accessibility (Fig. 4). It is inevitable that an initial layout will include a crop of ineffective and clumsy features.

Fig. 4

Following the usual approval tests covering undercarriage and flap operations, the system can be installed in the prototype with much reduced chance of further modification. The other systems can be treated similarly, so a stage is created when it is possible to prepare the installations for production, without adding to the turmoil of producing the prototype in time for the SBAC Show.

If this plan is adopted, it is of course essential to get the specimen in time. Many short cuts in its building are possible, as the structure does not have to be airworthy nor aerodynamically 'clean'.

This form of development, carried out without distracting those engaged in advancing the general progress of the prototype, can be directed towards final production arrangements.

Later use to which the functional mock-up may be put includes the life testing of certain components and the trial installation of new equipment.

The Basic Structure

We can now turn to the basic structure. The evolution of aircraft structures has reached a fairly stabilised form, in which strength and stiffness is provided primarily by the external skin reinforced by longitudinal stiffeners supported on transverse frames. As the relative proportions of skins and stiffeners are determined by natural laws, the choice of shapes is usually restricted to those shown in Fig. 5. Probably the Z section is the best compromise; in the larger members these can be extruded. When the call is for thicknesses less than can be obtained by this process, then rolled sections can be employed.

At one time it was thought that the stiffeners could be attached to the skin by spot welding; few now have any faith that this method can be made reliable. The only alternative to riveting appears to be a bonding process. In either case, there is much merit in breaking down large surfaces into panels for sub-assembly, thus permitting free access to both faces.

In the case of wings, it is sometimes possible to assemble the surfaces of the main wing box as separate items (Fig. 6). This clearly gives free access to the rivets, which can be squeezed by machine instead of hammered. One feels that this method of building up wing panels should be retained wherever possible rather than adopt the type, now coming into use in the States, in which integral stiffeners are obtained by machining out of a solid slab.

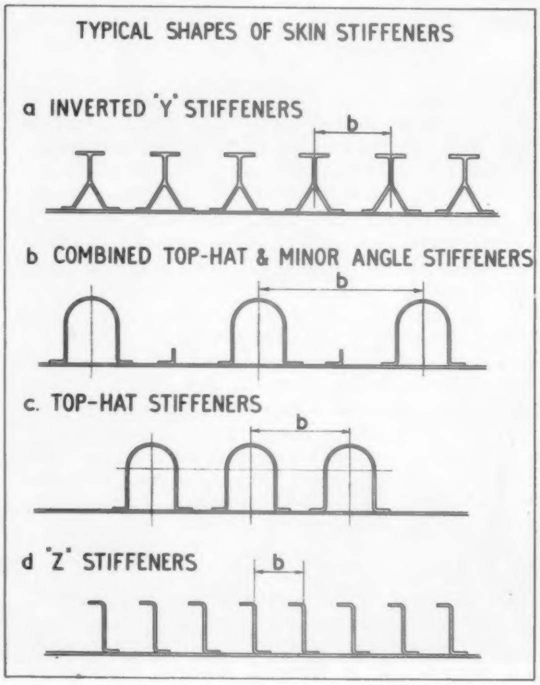


Fig. 5

Fig. 6

The wing panels together with the spar webs and ribs can be placed for final assembly in an external jig (Fig. 7), which gives the best chance of close control of the external shape.

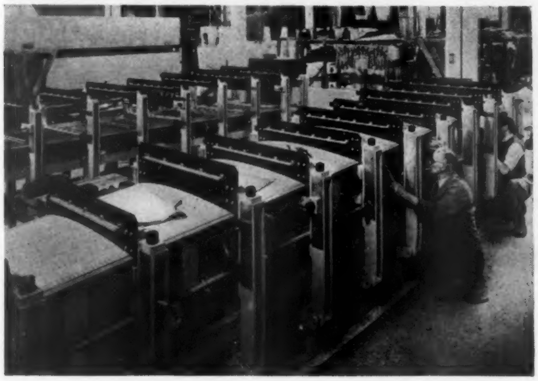


Fig. 7

The assembly of the wing box is, of course, more complicated if compartments forming integral tanks must be sealed to contain the fuel. A design employing flexible bag tanks is an easier manufacturing proposition, but it implies a small sacrifice in weight.

As with the wings, so with the body, though in this case because of the smaller loads, there is greater freedom in choosing the size of panels for sub-assembly. Again they are brought together in an external jig. (Figs. 8—11 inclusive.)

One important difference between the body and the wing lies in the preparation of the skin covering. By far the greater proportion of the body surface has double curvature and so it is not possible to use simple developed sheets. Not only is a forming process on the skin necessary, but all longitudinal parts attached to it are curved and the flanges of transverse members require complex setting. This unfortunately is an unavoidable arrangement.

But on the wings there is no reason for departing from straight tapers. Even curvature in plan form at the tips should be kept as short as possible, especially if the tip must be made detachable. The same is true for other aerofoil surfaces (the fin and tail plane). For a long time it was thought that a fancy shape fin expressed individuality. With ducted leading edges distributing hot air for anti-icing, and trailing edges carrying trim and/or servo tabs, double curvature not only adds quite unnecessary manufacturing complications, but also increase the difficulties of reproducing accurate contours on critical controls.

Suitable Jointing

I have previously suggested that I do not believe that spot welding can provide a suitable joint for primary structures. By comparison, rivets are crude in conception but effective in practice ; this latter is the main reason why they are so extensively used.

Rivets whose heads are not exposed to air in motion may be snap-headed and present few problems. Those which by reason of aircraft performance needs must be flush, and sometimes air- or fuel-tight as well, may require a number of separate manufacturing processes. The sheet, if too thin to be cut countersunk, must be dimpled ; the simple punching method giving an inferior result to "hot dimpling" (by the use of a spot welding machine). This in turn is less reliable than spinning. Finally, in very high performance aircraft, the exposed head may have to be surface milled.

The whole operation of closing close controlled flush rivets involves a sequence of operations, beginning with a preliminary assembly of the structure in the jig for the members to be drilled, removal for countersinking and reassembly for closing. The designer should be careful to confine such rivets to those areas where laminar flow is feasible, where fuel or air under pressure is contained within, or where slipstream buffeting can induce skin cracking.

In the less critical areas, the design should permit the use of fully automatic machines such as the "Erco," which is fairly rapid in operation. In this case the job must of course be taken to the machine.

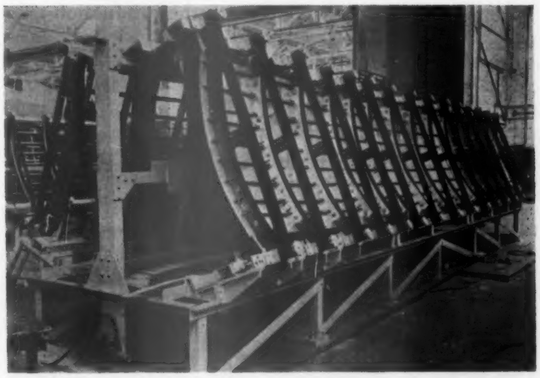


Fig. 8

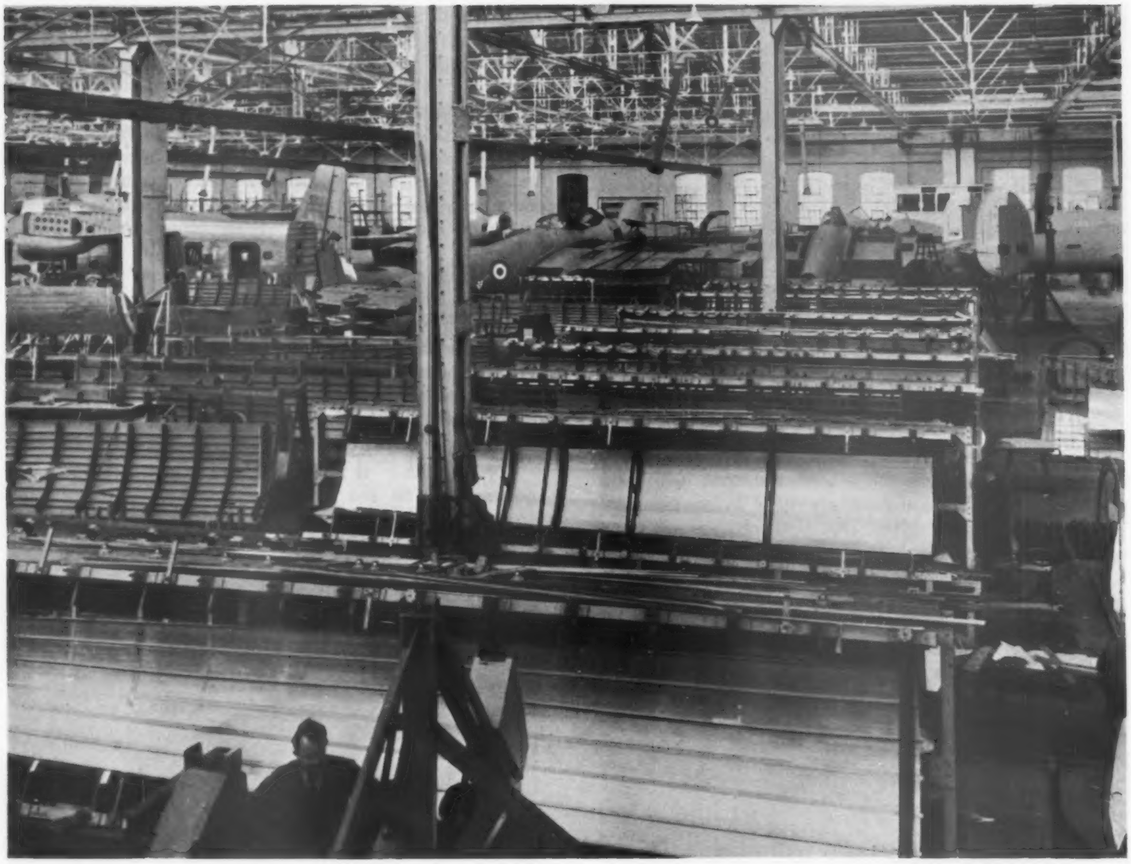


Fig. 9

When it is not possible to arrange access to both faces of a joint, we are grateful for the various types of tubular rivets.

Developments in Adhesives

Some of the older engineers on the production side may well retain a nostalgic affection for wood as a structural material. With the aid of a pot of glue and a mouthful of brads, aircraft grew visibly from day to day. While there is no prospect of reverting to rural materials, recent developments in adhesives for metals open up new possibilities for area jointing as an alternative to point attachments by rivets.

There are many technical advantages in this process. For example :—

1. The main problems in designing compression structures arise from elastic instability inherent in thin walled members. As the support between two adjoining members is mutual it follows that the more secure the mating face, the stronger will be the interaction. Two parts riveted together buckle at a stress dependent upon their *individual* dimensions ; if stuck together, the local buckling stress is determined by the combined thicknesses.
2. The external surface is usually smoother, as some distortion around rivets is difficult to avoid.
3. By eliminating holes stress concentrations are much reduced ; where bolted joints are essential the stress can be reduced by adding local laminations. Thus the fatigue life is increased.

Summarising these advantages, a bonded structure can be stronger and/or lighter, smoother and have a longer life than a riveted structure.

In production, bonding is carried out by two main techniques, the one using a heated press, the other an autoclave. It is of course simpler if the press can have flat platens. A large variety of panels complete with stiffeners and reinforcements can be assembled in one process, almost invariably with fewer man hours and at less cost than would be required by other methods. The list of possible applications include leading and trailing edges, flaps, control surfaces and tabs ; doors, bulkheads and ribs.

Fig. 10

Figs. 12, 13 and 14 illustrate examples of bonded structures.

Few, if any, designs have taken full advantage of this process, partly because it takes time to build up understanding and confidence and partly because sufficient equipment is not yet available.

It may be that a form of bonded shell could contain a core to produce a type of sandwich construction. Basically, this type derives its strength from two outer skins fully stabilised by the support provided by a light filling. Certain wooden aircraft successfully employed this form of construction, using balsa wood between plywood. Balsa wood with its grain normal to the surfaces has also been used between aluminium alloy sheet, but its density is too high and variable to be really attractive. To compete with other forms of construction, the core should not weigh more than about 2½ lb. per cubic foot. Although certain plastic foams having a density approaching this value are being developed, I do not believe that major structural components can be made more easily and cheaply by employing sandwich construction. The tools required would inevitably be large and complicated. It may be reasonable, however, to make certain small items such as tabs, bulkheads and doors by pouring the filler into pre-formed skins, but the applications would not be sufficiently numerous to have any significant effect on an overall production effort.

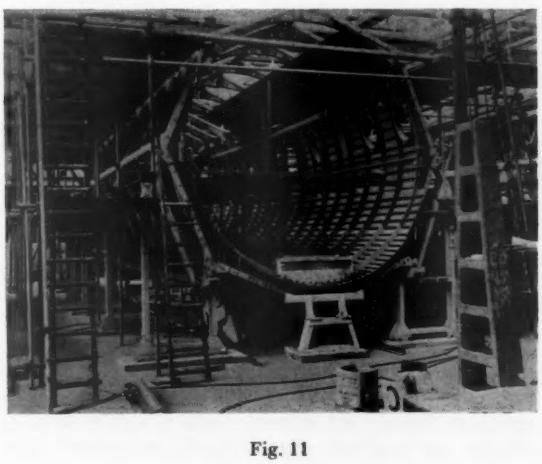


Fig. 11

Fig. 12

Wider Scope of Plastics

The strong plastics have a wider scope. This group includes asbestos-based phenolic resin, such as Durestos, and the glass-based polyester resin, such as Fibreglass. If the right technical application for these materials can be found, their unique production characteristics offer a great saving of cost and man power. Unfortunately, the use of these plastics in primary structures must be confined to small aircraft, in which case small numbers can be produced

Fig. 13

by the vacuum moulding technique developed at the R.A.E. Large numbers could be handled more economically by using heated metal moulding tools in a hydraulic press. Such treatment, however, does not come within a review of large aircraft.

But whatever the size, there are important uses to which plastics may be put. For example, air conditioning ducts which, in civil aircraft, form a not inconsiderable network. Early systems were designed for fabrication in aluminium alloy sheet, but experience proved that the ducts, especially those close to the blowers, had extremely short fatigue life. In addition manufacture was extremely expensive, calling, as it did, for skilled tinsmiths' labour.

A solution to both problems was found in the development of ducts wound from glass tape and impregnated with cold setting polyester resin. The results were most satisfactory, showing a substantial reduction of weight, unlimited fatigue life and a great saving of time and cost. This led to the use of Durestos for the more complicated parts. The method used is the "no pressure" moulding, in which moistened filtered material is formed to contour over a male mould, cured at a temperature of about 100°C. and finally assembled by cold gluing. The tooling is inexpensive and as in the case of the glass tape ducting, all the fabrication processes are carried out by female labour. (Figs. 15, 15 (a).)

The list of applications is steadily growing, but it must be stressed that to take a metal structure and make a Japanese copy in plastic is bound to end in failure. The materials are expensive, but the net gains are considerable.

Among other materials, some of the magnesium alloys have attractive physical characteristics. Strength, weight and elastic properties all combine to suggest great possibilities, even in the primary structures of large aircraft. It is also amenable to rapid production techniques with tantalising prospects.

One can visualise planks with integral stiffeners obtained from extrusions of tubular form that have been slit and flattened. These could be joined together by a battery of automatic argon arc seam welders. Enough development work has been carried out to justify such ideas. It is probably true to say that there is only one major barrier to the adoption of magnesium alloys and this is their quite unsatisfactory fatigue life. If this defect could be overcome, the lot of Design and Production Engineers would be eased and the use of aluminium alloys rapidly diminish.

But while we must continue to prospect country which shows promise of yielding favourable material, until such material as we may find has been processed to meet the exacting demands of aviation, we must not indulge in idle speculation. We must be prepared to produce aircraft the hard way and be thankful for small mercies.

Structures *must* be refined to reach the essential standards of strength and stiffness for the least weight. They *must* be smooth and incorporate complicated mechanisms to operate controls, flaps, undercarriages and other devices to achieve performance values measured against an ideal, rather than against the more obvious competitors.

In arriving at our solutions it is essential that our engineering is based on irrefutable scientific knowledge free from prejudice. Fortunately, this approach leads to basic arrangements rather more simple than some conceptions of the past. Most of our complications today arise from the functions that aircraft have to fulfill, the provisions made to combat the perils of the elements in which the aircraft operates and our predicament of trying to get a quart into a pint pot.

Apart from a skill in detail design, which cannot be defined, the most useful contribution a designer can make to production is to break assemblies down to give free access for their fabrication, to take

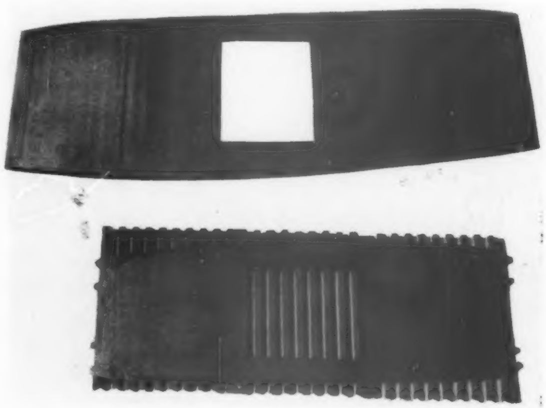


Fig. 14

Fig. 15

Fig. 15A

advantage of the special opportunities offered by bonding and to employ plastics rather than metal in parts requiring extensive manipulation.

But, above all, it is essential to carry out exhaustive testing at as early a date as possible, so as to minimise charges, alterations and modifications after production has started.

DESIGNING FOR PRODUCTION

PART 2

by R. W. WALKER, F.R.Ae.S.

Mr. Walker has been a member of the Hawker Siddeley Group for more than 25 years, having joined Hawkers in 1925. He has been with the Gloster Aircraft Company since 1937, when he was appointed Assistant Chief Designer, and took a leading part in the design of E. 28/39, the first experimental jet aircraft, and the Meteor prototypes. He subsequently controlled the design and development of the Meteor 7, 8, 9 series.

In 1948 Mr. Walker was appointed Chief Designer to the Company, with responsibility for the design of the Javelin.

Mr. R. W. Walker

THERE has been a good deal said and written over the past few years about the increasing complexity of modern aircraft. I make no apology for beginning on the same note: in fact, I do so deliberately, because I hope to be able to show that in spite of this, it is still possible for aircraft designers and Production Engineers to produce an aircraft which will both do its job as a good flying machine, and still remain a relatively economic proposition in production within the range of action over which they can exercise some control, namely, in the manufacture of the airframe itself.

Complexity in aircraft is something we cannot escape from—it is part of the increasing complexity

of life itself in the grip of scientific progress, with new thought and ideas being produced and developed more rapidly than they can be put into practice or turned to account.

The impetus to development given by the war has been maintained and, in fact, increased to an alarming degree by the uneasy world political situation which has existed since the war. The entry into the jet and atomic power age in a sweeping revolution has brought with it a host of new ideas in the technique of air warfare. We must accept complexity in the interests of survival.

Struggle for Performance

The fundamental reason for the increased complications of aircraft production lies in the struggle for improved performance—more speed—greater heights—longer range. The realisation that passing through the so-called "sonic barrier" is not such a formidable business as it was thought to be some years ago, has opened up a still wider field with seemingly unlimited possibilities.

The quest for increased performance has resulted in the need for a corresponding development in associated equipment. More powerful engines are needed, with their problems of increased weight, complications, and the amount of fuel they require.

Engine and flying instruments have had to be developed, capable of maintaining their accuracy under extreme range of speed and high rates of climb and descent. Gun armament has increased in weight and fire power. The effective combat life of a fighter in a single sortie can be counted in seconds, therefore accuracy is essential. Vastly improved radar for search and gunnery and other new navigation aids have been developed, to bring the fighter to its target with precision and dispose of it with certainty.

Guided weapons are further altering the picture, in introducing a still more deadly form of attack and requiring their own special types of associated equipment. The economic need to avoid having too many specialised types of aircraft in service has brought the two-seater fighter well to the forefront, as a weapon capable of being used in all varieties of weather and climate in any part of the world. With increase in operating heights, combined with high speeds, the problem of interception and identification becomes more acute ; fleeting contacts may be made and lost without any effective result; weather conditions may even prevent contact at all if reliance has to be placed solely on the pilot's limited range of vision without the support of guidance equipment.

The human element, the pilot, is however still the most important factor and instruments must be capable of recording with the same rapidity as thought. The training of a pilot is a highly costly item extending over a number of years. The first consideration in the design of an aircraft must be the crew, to enable them to do their job. Supersonic speeds must still be coupled with low landing speeds and a high degree of manoeuvrability over the whole speed range. The aircraft must present a smooth envelope to reduce drag, prevent buffeting, and provide a steady gun platform, with adequate strength to withstand all usable aerodynamic loading conditions without failure, and sufficient stiffness to avoid stability and control troubles through structural distortion.

I have outlined these considerations, by no means the sum total, to illustrate the inevitable consequence, i.e. that bigger and heavier aircraft with more stowage space are needed to fulfil their role under modern conditions and Air Staff requirements. The trend has been clear over past years. In the single-seater fighter class, we have had the Hawker Fury in 1930 at 3,300 lb. weight, the Hurricane in 1940 at 6,500 lb. and the Meteor in 1950 at a weight of about 15,500 lb.

Modern single-seaters are of the order of 12-17,000 lb. and two-seaters range from 18,000 to about 35,000 lb. This is reflected in the increasing length of time taken from start of prototype design to delivery of the first aircraft to the Service.

For the designer, it is a constant struggle to get the best out of two worlds—to keep weight down to a minimum, to produce an efficient fighting weapon and to produce it at the lowest cost in the shortest possible time. It must be borne in mind that, for an average fighter, every pound increase in the weight of equipment carried involves a corresponding increase in weight of structure and fuel to carry it.

There has been considerable speculation around the possibility of producing what has been referred to as a "cheap fighter". This is a very attractive conception, but as can be inferred, would require many concessions by the Air Staff and Ministry of Supply to make it realisable.

Effect on Airframe

From the broader requirements for the aircraft arise a host of problems affecting the design of the airframe itself. The pilot's and navigator's view must be as free from obstruction as possible. The hood and windscreen framework must be designed to give the maximum amount of transparency and, at the same time, be sufficiently strong to carry the enormous suction loads imposed during high speed flight. Moulded glass with double curvature is not yet a practicable possibility in the shapes required, and the necessity for using Perspex brings its own trail of difficulties to guard against contraction and cracking under extreme changes of temperature. Hoods must allow for the normal entry of the pilot on the ground and also be capable of being jettisoned completely in flight in any position. Provision must be made for rapidly dispersing ice and repelling rain on the outside and preventing formation of mist on the inside, all of which are a menace to the pilot through extreme changes of temperature during rapid climb and descent. Pressurised cabins are essential and the modern air conditioning system has to provide for adequate cockpit heating at altitude and under arctic conditions, and for refrigeration under tropical conditions.

Guns in like manner must be heated, but thermo-

statically controlled to prevent the danger of over-heating and rounds "cooking off". Much of the modern radar and electrical equipment must also be run at controlled temperatures. The fuel system becomes complicated; the fuel supply must be maintained under extreme temperatures, altitudes and rapid manoeuvres. Boiling must be prevented to avoid increase in fuel tank pressure and fuel loss through vapourisation during rapid climbs and operation at high altitudes.

Problems of aircraft control design have been intensified by increase in speed and altitude ranges. Changes of trim can take place at high Mach numbers, trimming tailplanes are now the rule and control surfaces must be capable of dealing with severe changes in aircraft behaviour and aerodynamic loading conditions. Power controls have to be provided either to supplement the pilot's effort or to replace it entirely. These must be duplicated as fully as possible to guard against a failure which may be catastrophic. Flutter can also be a serious menace — wings, tailplane and fin must be of sufficient stiffness to preclude this, and control surfaces must be inertia balanced to raise them beyond the flutter region.

Electrical equipment increases enormously in volume and complication. Accessory gear boxes have to be capable of carrying greatly increased loads from pumps, generators and compressors for the hydraulic, electric, and pneumatic services. Fuel after-burning as a means of increasing the jet thrust adds complications to the fuel system and problems of heat resistance. Servicing and maintenance needs become more severe with the increase in equipment, calling for a greater number of access doors which must be quickly removable and which add weight to the airframe structure. Radar devices demand many aerials which must be built into the structure for cleanness, and new dielectric materials for radomes, which must retain their strength properties under all temperature conditions and be sufficiently durable to withstand rain and hail at high speed.

Design Organisation

From the technical point of view, the success of a Company's product depends primarily on what is turned out from the D.O. and on the excellence of its staff. Design staffs in recent years have tended to become swollen in numbers to the detriment of the general level of work and with an increase in the problems of administration. It is desirable to keep down to the lowest number of staff practicable consistent with the business of getting through the design with smoothness in the shortest time, and to avoid having too many of the senior staff occupied in guiding the more inexperienced. A sound organisation is vital, with inter-departments well balanced in numbers and quality to avoid bottlenecks during the course of the work.

The organisation must have as its constant aim:

(a) reduction in design operating costs,
(b) increase in output of drawings,
(c) reduction in total time for design and construction of new type aircraft.

The dividing lines between technicians, designers and draughtsmen should be finely drawn. Interdepartmental chiefs should have a broad, tolerant outlook and should maintain constant contact with one another, with free interchange in discussion of the problems which constantly occur. In this manner, enthusiasm is transmitted down and the staff can work as a team rather than as a number of small sectarian groups.

Project Development

The Project Development Department is of the greatest importance in the early stages of design. It is here that valuable spade work is done, in taking the outline of the initial project and preparing the structural basis for passing on to the main Drawing Office. This involves a number of correlated scheme layouts to establish more precisely the disposition of engines, armament, fuel tanks, undercarriage, control circuits, crew, and the larger items of equipment, so that closer checks of all-up weight and centre of gravity can be made.

(*Courtesy of "Southern Daily Echo"*)

Break for coffee at the Saturday morning session. From the left are Dr. Russell, Mr. Cooke, Mr. W. E. W. Petter, Mr. W. F. S. Woodford, Air Commodore G. Silyn Roberts, Professor Richards, Mr. Puckey, and Mr. R. W. Walker.

The Project Development Department carries the initial design to a stage where components can be put into the Experimental D.O. with all fundamental information provided for drawings to proceed on a timed basis. This department should not probe too deeply into detail, but should concentrate on fundamentals to ensure that the structural basis as a whole is sound. The work must be done in conjunction with specialists in the Stress Office, who do a sufficient amount of calculation to advise on paths of load transfer and to establish approximate sizes of main structural members. Design changes inevitably take place after transfer of work to the main D.O., but coherence has been established and these changes can be dealt with without much difficulty. In addition to dealing with types in progress, this department carries out research investigations into new forms of structure for economy in design and manufacture.

Main Design Office

The Main Design Office carries the biggest burden. Here begins the business of combining ingenuity with the production of thousands of drawings from which parts are to be made. Main members are put into practical form ; subsidiary structure laid out without wastage, to house a mass of equipment, often in an early stage of development, in such a manner as to satisfy a host of technical regulations. All this must be arranged in an orderly way, so that in the finished aircraft easy access is provided to all pieces of equipment for rapid servicing and maintenance. One cannot attach too much importance to detail design. Every part must be necessary, must do its job, and be as light and as cheap as possible.

Modern complications have made it necessary to throw overboard the idea of having an Experimental D.O. to design the prototype and a Production D.O. to productionise it. I have known aircraft, even in the days of simplicity, which took a good deal longer to productionise than they took to draw experimentally. The huge increase in man hours now required and limitations in staff will no longer allow this. The only profitable course is to design for production from the out-set as fully as it is economical to do so, i.e. with the exception of selected smaller items which can be made easily by simple hand methods, without regard to tooling considerations at this stage.

This policy, of necessity, delays the start and build up of issues of drawings to some extent, and increases the total man hours in the D.O. to clear the prototype drawings completely. The additional man hours in designing for production need not be more than about 10%, since the rate issue of drawings is often governed by the technical problems which have to be dealt with before drawings (in whatever form they may be) can be released. Furthermore, a more gradual release in the first place allows the Works to put their own job on a firm footing and avoids a pile-up of drawings they cannot deal with. Through an orderly system, coupled with an increase in the total number of detail drawings which can be handled and spread more effectively, the nett result is, in fact, to *reduce* the total time for completion of the prototype and to place the whole design in an extremely strong position for putting into production if the aircraft should turn out to be successful technically.

The results of this amalgamation of experimental and production design offices are therefore :—

(a) a reduction in time to produce the first prototype and an assurance of repeatability of additional ones;
(b) a design staff placed in a position to follow straight through from prototype to final production without dislocation;
(c) an appreciable reduction in the total D.O. time to clear production drawings to the Works;
(d) a guarantee of accuracy of the drawings;
(e) from the first prototype the designer knows the worst (subject to possible changes after flight tests) as regards structure weight, and can forecast with some accuracy the all-up weight of the aircraft for the Service;
(f) a means of forming reliable estimates of cost of tooling and manufacture for production.

I should make it clear that the foregoing remarks refer to Design Office procedure up to the introduction of a type into production and into the early stages of its life in the Service. By that time, the aircraft is sufficiently stabilised to allow it to be taken over by a Development Drawing Office to deal with routine modifications and trial installations. Variants of the basic type would continue to be dealt with in the main design office.

Stress Office

Before the serious introduction of stressed skin construction, the Stress Office was always something remote; there for the purpose of supplying diagrams of loads with arrows indicating directions, its staff having very little knowledge of or interest in what was really going on in the D.O. The stressman can be made to feel he is part of the general plan in the production of the aircraft by being given a programme, linked with that for the D.O., and by encouragement to discuss design on the boards in the early scheme stages. A system of preliminary stressing of principal schemes to establish size of frame members and plate thicknesses saves much time in the D.O., and can often result in simplification and weight saving. All final assembly and detail drawings must, before issue, pass through the Stress Office for careful scrutinising and check of every part. A weakness in some important stressed detail part which could be given an ample reserve at the cost of little or no increase in weight, can be just as fatal as the failure of a main member. It is necessary to have a number of mathematical specialists, but a strong, useful and reliable department can be built up by encouraging transfers from the Drawing Office of young men with a few years of design experience, and preferably some works experience, who have an aptitude for calculations.

Aerodynamics Department

At first sight there appears to be little connection between this department and production design, but judgment in what is of importance in aerodynamic cleanness is, in fact, very valuable. Complications in manufacture can often be avoided by a judicious tolerance, which will allow some latitude from the ideal in regard to contour tolerances and faired shapes, etc.

Design Office Planning

To get the maximum effort out of the Drawing Office in a smooth and orderly way, it is necessary to have a carefully considered comprehensive system of planning and progress records. This is of value in encouraging the staff to be "programme conscious". The overall design programme must be staged and charted according to priority requirements for drawings issues, and man hours estimates prepared for each component or system, with an appropriate allocation of man power built up for each month. It has been found profitable to make an extract from this for each Section Leader, specifying his part in the programme in drawings output and man hours and for him, in turn, to produce a monthly progress report in a standardised form. From these records monthly summaries are made of the essentials, i.e. design times, man power and drawings issues, which are charted against the programme to show the trend. By this means effective control can be maintained during the detail design stage, and any serious departure from the planned programme can be detected at once and steps taken to rectify it. The planned programme is, needless to say, never fully realised, but the procedure serves its purpose in encouraging the Section Leaders to keep their own programme constantly under review and simplifies the work of the design executives. There is no attempt to turn the Design Office into a machine, and the system can be followed without loss of individuality on the part of the staff.

The Mould Loft

In the early days of production of the Meteor under war conditions, it was necessary to sub-contract some sections of the design and manufacture. Drawing board layouts were relied on to produce lines and details, and the experimental department followed up with developments on wooden tables or metal plates. The result was some measure of chaos, owing to the fact that there existed no reliable master layouts to ensure accurate duplication or matching of parts. This led to the purchase of a Lanston Monotype camera to lay the foundations for the development of a system of full scale layout and template reproduction, which now forms an integral and a most important part of our design organisation. Full scale lofting proceeds in parallel with work in the Design Office. Lines are calculated, laid out from the start and followed up with layouts of all sub-assemblies, for the purpose of checking drawings and supplying dimensional information to the draughtsmen for matching parts. These lofting plates are used for template reproduction from the start of prototype manufacture. We find that full scale layout time is of the order of 20% of the Experimental Design Office time, and for a prototype aircraft requiring about 8,000 drawings, template requirements will be around 1,200, principally for contours. Production requirements will increase the number to about 5,000.

The basis of template methods is to provide the Shops with :

(a) means of making frame and rig assemblies,
(b) master developments of fittings and skins for manufacture, profile and drill templates, bend blocks, Hufford press blocks, etc.,
(c) means of locating sub-assemblies in relation to frames and remaining structures.

Frames are drawn full size and include webs, edge members, stiffening plates and details fitted to the webs. Some frames may have as many as 30-40 detail templates, which by normal photographic methods can be supplied as single items for tooling and manufacture. Accuracy in this way is guaranteed for profiles, drilling and location.

We use two methods of reproduction; firstly, by straightforward camera methods and secondly, by the use of Astrofoil and contact printing. The second method (which is being developed) offers a big reduction in cost and is of particular value in dealing with the smaller details, leaving the larger and overlaid parts to the more complicated and usual negative/positive camera process.

The Mould Loft staff necessarily fluctuates during the course of design, principally in accordance with the template requirements of the Works, and it may be noted that the Department is under the control of the Design Office.

Collaboration between Works and Design ensures that the needs of the Works are met for photo-templates for both prototypes and production. Master layout accuracy ensures that sub-contractors can take over sections of even a prototype air-frame and produce matched sub-assemblies or components.

Research and Development Department

The Research and Development Department can be built up to form an invaluable adjunct to the Design Office, which it can relieve of a considerable amount of work in the prototype stage. With modern aircraft, pre-design and pre-flight testing of systems has become essential. Full scale test rigs must be made—for the fuel system so that all component parts can be tested in all altitudes of flight—for pressure cabin, heating and refrigeration systems—and for the complete hydraulics and power control systems under simulated flight conditions. It must be ensured that all these systems function correctly before final drawings can be issued to the Works.

The Research can be brought into consultation with the Design Office in the very early stages, given the basis for the design and the proposed run of pipes with approximate lengths for the systems to be improvised and developed. The inventiveness of the Department can supply answers for the D.O. to translate into manufacturing drawings. Small component parts are developed and made, such as flow

proportion valves, thermostatic controls, flow restrictors, etc. A small Design Office in the department develops these ideas, and eliminates guesswork by contributing to theory and proving in practice. The ironmongery of test rigs is drawn out and made on the spot when practicable. All this work can be extremely effective in shortening the testing time in the Experimental Shop and the Flight Shed.

Design and Production Co-ordination

So far, apart from reference to the Mould Loft, I have touched almost entirely on technical aspects of design which can only be dealt with by the Design Office itself, during the most interesting and indeed most anxious period, when the foundations are laid which can make or mar the job, when an unwise decision can lead to complications later or even to a major weakness, not discovered until flight trials are started, which cannot be rectified without extensive re-design.

When one gets down to the business of designing the airframe and its installations, there is another aspect which is vital to the economy of production, that is, the link between the Design and Production Departments.

There was a time when the prototype was the designer's pet, surrounded by an atmosphere of mystery—none must see it, least of all the people who may be called upon to produce it in all good time; in fact, it was not the fashion for the production people to be particularly interested in it. Prototypes were built in a self-contained experimental shop until the aircraft was "released for production", the factory production departments having virtually no knowledge of it or its attendant problems. With the inevitable increase in time taken to get an aircraft into production from the design stage, we cannot now afford to concentrate entirely on the manufacture of prototypes irrespective of their future, and run the risk of extensive re-design to make them producable. This was realised at Gloster some years ago and during Meteor production, closer contact was built up between the design production departments.

Design Production Committee

At the outset of the Javelin, it was decided to put this contact on a firmer basis and a Design Production Committee was set up to hold regular meetings, with the permanent membership of:

Design	*Production*
Chief Designer	Production Manager
Assistant Chief Designer	Project Engineer
Chief Draughtsman	

The Chief Designer and the Production Manager co-opted, as necessary, various members of their respective staffs best qualified to discuss in detail the various items on the agenda.

The terms of reference of this Committee were defined as:

"To maintain the closest co-operation between design and production.

"To review current and projected design work having production implications.

"To arrive at agreement on basic schemes, omitting general detail covered by the Process Planners.

"To keep under regular review estimated dates for completion of drawings.

"To note production principles and standards to be observed in design.

"To note new production methods introduced and changes in manufacturing policy in the Works.

"To establish possible production quantities as a basis for design and tooling.

"To establish principles of break-down of drawings for economical production, consistent with a minimum of Design Office work."

Methods of Operating

Because the Design Department was some little distance from the factory, production personnel were stationed in the D.O. under the control of the Project Engineer, to advise on methods, makability of parts, etc. This staff maintained close contact with the structural design from the project development stage, and followed the detail design by drawing-board contact through all its prototype stages.

The Committee devoted considerable time to the discussion of the initial aircraft break-down. The optimum design and production break-downs were considered concurrently, since the ability to produce efficiently is dependent upon the basic design conception, the equipment available and the concentration of labour possible.

The policy of the Company to build prototype structures in the Production Shops brought the pre-production departments in close touch with the aircraft from the outset. Through this active participation, interest and enthusiasm were displayed throughout the building of the prototype and have since been effectively maintained.

This close co-ordination between Design and Production could not have been achieved if the production personnel had been holding a watching brief, while a separate Experimental Department had built the aircraft.

This building of prototypes by production personnel has in every respect well justified itself. It has laid a foundation for Production without in any way sacrificing the prime requirement of a prototype, namely, to get the type into the air as quickly as possible.

A schedule of Component Building Priority was, in the first place, tabled by Production and a drawing issue programme to suit this was agreed and issued by the Design Department.

The main breakdown having been agreed in principle, structural design schemes for the respective components were developed in accordance with the Priority Schedule. The closest contact was maintained during this period, as it was then that suggestions and alterations could best be effected. This enabled detail design to go ahead with precision, and avoided subsequent hold ups by eliminating the need to re-draw parts at a later date for ease of manufacture.

The Production Department tabled their requirements for lofting in accordance with the priority

sequence. This gave the Drawing Office time to organise, thus obviating major template delays.

For information on methods of jigging and tooling, the pre-production departments issue to the D.O. Tooling Standards giving the plant available, and the production capabilities of it.

Through this system of co-ordination, the prototype provides experience for production and the same sequence of sub-assembly and final assembly can be followed with little revision. The result is a complete absence of upheaval in the transition, since the same teams work together on the next step of a project with which they are thoroughly conversant.

Through the policy of designing sub-assembly and main assembly jigs in the main Jig and Tool D.O. and controlling detail tooling from Process Planning, the Works are able to use a considerable amount of the prototype tooling expenditure towards production. The jigs are, in fact, an elaboration of those built for the prototypes.

One must not imagine that collaboration to this degree of intimacy is always conducted in an atmosphere of calm and sweet agreement. The designer's instinctive reaction often appears to be to do his best to see that the production people do not get what they demand, which may be a short cut to a production paradise, and the production man may be firmly convinced that the designer is only a pure theorist. But these things can be thrashed out. The scheme works and has the result of making both parties become interested in the other man's job, and take a broader view of his own. A healthy competitive spirit encourages ideas and ensures that sound reasons govern the proposals that are accepted.

Design for Production

In determining the basic design, that is, in the initial project stage, it is possible to give some consideration to the longer term production possibilities of the aircraft. Two things we know will increase in weight, the power units and the military load to be carried. Structure weight will increase in consequence, and it is always profitable to make some allowance in reserve of strength, stowage volume and choice of wing loading, to provide for future developments and to avoid "saturation" of the airframe. This can be done without serious handicap to the performance of the aircraft in the first place: indeed, aerodynamic considerations, at least in a twin-engined aircraft, may demand lines which provide redundancies of space that can be turned to good account.

A fighter can be calculated to follow a pattern in development if the original design proves to be satisfactory, and in this a twin-engined aircraft is more amenable than a single-engined one. A striking example of this lies in the Meteor, which from the original fighter version has gone through progressive development stages into production as single-seater photo-reconnaissance, fighter-reconnaissance, two-seater trainer and lastly night-fighter, with facility in each role, and economy in cost.

Again, allowance in the airframe envelope can be made for alternative power units and for the development of engines of greater power. At least a dozen types of power unit of wide variety, size and shape have been installed in the Meteor within the past ten years, with comparatively little dislocation to the airframe structure.

Prototype Design

It will be found that the principles of construction are dictated largely by past production experience in what has proved successful, and that nothing revolutionary is to be expected. Advantage is taken of research development, where this is practicable, without running the risk of embarking on anything that may be unsound and from which there may be no means of turning back. The particular shape of airframe envelope and mass distribution regulate very largely the disposition of the main members. Stressing and stiffness considerations will decide the size of those members, whether single or double spar construction is to be used, how main frames may be spaced and how ribs and section stiffeners shall be disposed. Although new forms of construction are being widely investigated, simple frame and skin structures have not yet been superseded, largely because they provide a means of distributing stresses economically, permit the design to be built up stage by stage, and finally give a high degree of flexibility for subsequent local structural alterations which are bound to occur.

Certain principles can be kept in mind during the design, which will assist in cutting down prototype costs and ultimately production costs for whatever quantities may be required:

(a) sound structure for minimum weight;

(b) smallest number of parts consistent with ease of manufacture;

(c) simplest form of design for each individual part;

(d) design within the known (or projected) capacity of factory tools and equipment.

Break-down of Aircraft

The break-down into principal components is required essentially for convenience in manufacture, transport and storage. From weight-saving considerations the fewer joints there are the better, and even from the manufacturing point of view every joint adds so much cost to the finished job. These usually cover certain natural divisions in the airframe in the first place, but in larger aircraft, components may be split into major assemblies to facilitate jigging and manufacture; for instance, the wings may be assembled in two sections and fuselage in two or three, to reduce time in the jig.

The structural sub-assemblies are arranged for convenience in making up sections such as complete bulkheads, spar assemblies, wing nose portions, cockpit walls, deckings and floors, etc. Detail sub-assemblies consist of hydraulic panels complete with

valves and pipes, ribs, frames and doors, and small bench assemblies.

In this process of break-down from major to minor items, it must be ensured that all structural joints are made with a minimum number of fastenings and loss in weight, and that assembly can be carried out in correct order and with complete accessibility to fastenings.

Jointing

In considering the means to be used in joining together the thousands of parts which go to form the final built-up structure, riveting is most common on account of its reliability compared to welding or adhesive processes, and its adaptability in manufacture and inspection. Riveting is comparatively cheap, permits work to be widely spread and facilitates rapid expansion in the Works.

Choice of Materials

Although weight-saving must always be a primary consideration, it is important to confine the choice of materials as far as practicable to those with known characteristics. The higher grade double heat treated light alloys are now established and available in quantity, but a policy of caution is advisable in their application to avoid their use where manipulation or heat treatment may prove to be a possible difficulty in production. In a great many parts of the structure where stiffness or panel buckling, and not strength, is the criterion, or where a theoretical sheet thickness cannot be worked down to for other reasons, the lower grade alloys will suffice.

Sheet

Details from sheet requiring manipulation within a very short time of solution treatment, followed by final heat treatment and correction, need very careful control and inspection in the Works and can cause scrap and delay. It is advisable, therefore, to restrict the higher grade sheet to simple unformed details such as spar and frame webs, " laid on " skins, and nosing skins for wing tailplane and fin, which present no difficulty.

Extrusions

Double heat treated extrusions are best used in the straight, e.g. spar booms, or where forming can be done safely in the fully aged " as received " condition, thus avoiding a sequence of operations such as rough machining, solution treatment, forming and final machining. Extruded sections must in any event be carefully designed to avoid splitting along sections too narrow, badly graded or at bolt holes.

Forgings and Stampings

Forgings are essential for joints between main structural members. They can be used with great advantage throughout the structure, but should be used with discretion, consistent with avoidance of a big increase in complicated machined details for the airframe as a whole. Their basic value is to simplify manufacture and assembly and to save weight by :

(a) reducing the number of parts in replacing fabricated details ;
(b) providing machined faces for accurate matching ;
(c) reducing the number of fastenings required ;
(d) allowing free play for the tapering off of strength so often required along a member in bending ;
(e) consistently repeatable accuracy.

In recent times, sizes of forgings have tended to increase and the use of the larger forgings can be limited, by manufacturing facilities. Some use is being made of long forgings for spar booms, the economy in these cases being weight-saving by making end joints integral with the boom section, and cost-saving by largely eliminating the special fittings and bolts demanded at these points of large load concentration.

The number of light alloy forgings should, however, be kept down to a practical minimum consistent with simplification of structure, particularly in the high grade materials, where the long precipitation period may be a strain on heat treatment capacity. Machined bar or billets used in place of forgings and stampings for prototype details must allow for cross-grain weakness, on the understanding that forging sizes will be reduced for production.

Steel forgings will be used principally where there is need for a high stress concentration within a small space, and in the more complicated fittings it is advisable to use die forgings even for prototypes, in order to get the correct grain flow. This is more uneconomical, but the dies remain available for production. Steel castings will be found more expensive and require more elaborate test procedure.

Light Alloy Castings

Light alloy castings are in general use in small quantities as they provide light rigid structures. The double strength factor for castings calls for particular care in their use to avoid possible losses in weight. Often there is no alternative where local rigidity is more important than weight, or where the one-piece casting eliminates an untidy assembly made up of numerous complicated parts.

Systems and Installations

These are separated into two broad categories—those which are an integral part of the airframe, such as flying controls, hydraulics, engine installation, fuel system, pressure cabin and heating ; and those which are never stabilised at the time of the first prototype aircraft, such as the cannon installation, radar, radio and instrumentation. To accelerate completion of the first prototype, it is customary to omit the operational equipment and to equip the aircraft for handling and performance trials, leaving Service equipment to be fitted in later prototypes. New types of equipment continue to be introduced even during design stages, which involve a succession of changes and installation differences between one prototype and another, and this makes it impossible to stabilise the design until it is finally decided exactly what shall be fitted to early production aircraft. Systems and installations, therefore, as a whole, take up more D.O. time than does the design of the structure itself. Electrics are

(*Courtesy of "Southern Daily Echo"*)
Mr. F. C. Cooke, Mr. W. E. W. Petter, Mr. W. F. S. Woodford, and Mr. J. W. Taylor discuss one of the morning Sessions.

invariably the last item to be cleared, and considerable judgment is needed to arrange junction boxes and cable harnesses with sufficient flexibility to allow for subsequent changes in equipment, without extensive re-design and wiring runs, which in turn affect structure and tooling. Airframe systems, as mentioned earlier, must be designed in principle and proved by rig tests for functioning. These usually involve a great many proprietary parts from firms specialising in the design of equipment for hydraulics, brakes, air conditioning and electrical systems, etc.

Mock-up

An accurate mock-up of the entire aircraft is essential at the start of the design. This is usually made of wood for the prototype, and should have main members and frames reproduced in location and in sizes as far as is practicable. The greater the accuracy, the more valuable it is in allowing equipment to be positioned and cables and pipes to be run faithfully. It is used for all fundamental design checks of installation, seating positions of crew, cockpit arrangement of controls and instrumentation, and hood and windscreen arrangement to give the best possible view.

If production of the type has been decided upon, it is profitable to have an additional mock-up of the fuselage in metal structure form made from prototype tools. This provides an exact specimen for the Design Office for establishing accurately runs of pipes and cables, and mounting of equipment, and allows a clear picture to be formed of any proposed alteration in structure or equipment before D.O. work is begun.

Structural Tests

A major test programme is laid down in the early design stages. This normally covers the range of main components for testing the complete airframe, and involves the building of virtually an additional complete structure, i.e. the complete fuselage, tail unit, windscreen and hood, undercarriage and one wing. These tests are not necessarily carried out before the first prototype flies, but are wanted as early as possible to discover weaknesses which may affect production drawings and must be done before the first production aircraft is released. The components are tested independently, and they impose a considerable load on the D.O. to design elaborate test gear and dummy loading rigs. Besides those, a number of minor tests are found necessary as the design proceeds, to cover such items as frames, panels, ribs and fittings where stressing is uncertain and *ad hoc* confirmation of strength is needed.

Presentation of Drawings

Designing for production involves the preparation of drawings to production standards for the prototype, under a more elaborate system of detailing grouping and dimensioning of parts than would be used on a purely experimental basis. Broadly speaking, structure drawings are fully detailed, but systems and installations are drawn in experimental or semi-experimental form where they are to be proved on the first prototype, or are in doubt for production. The Design Production Committee discussed this in great detail and established a procedure acceptable to both D.O. and the Works. The aim is to eliminate lost time in the Works departments, simplify the work of process planning and inspection, and facilitate storage of parts. Detailing of parts is extended, but simplified by minimising the use of matched holes, unless fitted holes are required. For large assemblies such as spars, and bulkheads, holes are dimensioned on one part only, the web drawing. Dimensional accuracy is ensured by the full scale layouts, and all structure drawings pass through the Mould Loft for final check before issue to the Works. The S.B.A.C. system of drawings grouping and numbering is used throughout.

Production Design

By virtue of the earlier preparations, production design becomes, in effect, an extension of the prototype drawings. Structurally, changes will be confined to the incorporation of improvements arising from prototype flight tests, structural strength tests, and minor sub-assembly grouping changes. Drawings are completed for tooling of those items which for the prototype had been made by hand methods, such as access doors, etc., now calling for the use of press tools. More accurate contour control for wing and tail surfaces will be necessary to ensure consistency in handling characteristics of production aircraft. This need call for nothing more than a definition of local tolerances, which will enable the Works to decide if the mechanical press or rubber press is to be used. Additional forging drawings are introduced, where desirable, to cover items machined from the solid for the prototypes.

During prototype construction, the Air Staff and Ministry of Supply will have issued a stream of new requirements to improve the aircraft operationally ; new devices, more modern equipment, fresh conditions to be met. Some of these will have been dealt with during the course of design, others have to be assessed in relation to the production programme, to guard against possible delay. A Production Specification is drawn up to stabilise the design and to define what can be accepted for the first aircraft. Those items omitted will be introduced subsequently into the production line as modifications. These changes affect principally the installations, but invariably call for some alterations to subsidiary structure. It is in this work that the bulk of the D.O. time is taken in productionising the drawings.

Conclusion

In the time allotted, I have been able to do little more than touch lightly on some of the vast numbei of factors embraced by the title of the paper. Security considerations have precluded a detailed description of the Javelin, but the principles described have been applied to its design and construction.

The delta configuration brings its own peculiar problems of stressing and structural design, but these are no more formidable, perhaps even less so, than those applying to more conventional forms of swept-back wings.

Many other subjects are of current interest, such as integral construction, machined contours, the use of large presses, and the development of new materials. These are part of a new philosophy which may have a big effect on aircraft designs of the future.

The romance of flying is still with us, but it is necessary to come down to earth to grapple with the maze of laborious detail which goes to make up the modern aircraft, and which demands the utmost in painstaking care.

FIRST SCHOOL OF WORK STUDY

WORK study is generally agreed to be one of the most rapid and short-term ways of increasing output and productivity, yet the facilities in Britain for training and research have been confined, until now, to short courses run by a few technical colleges by certain large scale industrial organisations for their staff, and by consultants for their clients.

In Germany and France, however, there have been for some time central organisations for the training of work study personnel serving industry as a whole, and the absence of a similar organisation in Britain has been a serious handicap to the application of Work Study in this country.

This deficiency was one of the matters investigated by the Joint Committee of the Institution of Production Engineers and the Institute of Cost and Works Accountants when preparing their recently published Report, " Work Study—Application and Training," and it is therefore encouraging to learn of the establishment of a residential school to provide a course for the final training of Work Study officers capable of undertaking immediate investigations. This institution, known as " The Work Study School " has been established at the College of Aeronautics, Cranfield, with the support of the British Institute of Management, under the general administration of Professor J. V. Connolly, B.E., F.R.Ae.S., M.I.Prod.E., Head of the Department of Aircraft Economics and Production at the College.

The Director of Studies responsible for the teaching in the Work Study School is Mr. H. C. Wiltshire, M.Sc., M.I.Mech.E., M.I.E.E., M.I.I.A., and an Advisory Committee, composed of representatives of organisations concerned with Work Study and a number of authorities in this field, has been formed to collaborate with the College in the determination of the requirements of the Syllabus and the courses to be given. Members of the Committee include : Mr. T. H. Windibank, C.B.E. (Chairman), Mr. B. H. Dyson, M.I.Prod.E., F.I.I.A., Mr. R. M. Currie, M.Inst.C.E., M.I.Mech.E., M.I.Prod.E., Mr. R. Wynne Roberts, Mr. E. Fletcher and Mr. W. F. Floyd.

Mr. Dyson, it will be recalled, was Chairman of the Sub-Committee which prepared the Report on " Work Study—Application and Training."

There will be three courses of ten weeks' duration during the year, the first of which commenced on 12th January, 1953, and the fee is 200 guineas inclusive. Courses will be limited to twenty students in the first instance, and special consideration will be given to small firms wishing to send students.

Full particulars of the syllabus may be obtained on application to " The Work Study School," Cranfield, Bletchley, Bucks..

NEWS OF MEMBERS

New Year Honours

The Institution is pleased to record that the following members were honoured by Her Majesty the Queen in the recently published list:

C.B.E. Mr. W. J. Mason, Member, Director of Ordnance Factories, Ministry of Defence, Government of Pakistan.

M.B.E. Mr. L. A. Jouning, Associate Member, Works Manager, Aron Electricity Meters, Ltd., London.

M.B.E. Mr. H. Moliver, Member, Personnel Manager at Vauxhall Works, Stockport, of Craven Brothers (Manchester) Ltd.

MR. S. A. J. PARSONS

Mr. S. A. J. Parsons, Member, has been appointed Principal of Wellingborough Technical College and took up his new duties last month.

S. A. J. Parsons

Mr. Parsons, who was formerly in charge of the Production Engineering Section of the Birmingham College of Technology, is a member of the Birmingham Section Committee and also serves on the Institution's Membership Committee.

MR. J. M. STEER

The Institution sends good wishes to Mr. J. M. Steer, Associate Member, and former Hon. Secretary of the Adelaide Section, for his speedy recovery from a recent operation.

Mr. Steer has unfortunately found it necessary to relinquish his duties as Section Hon. Secretary, which office he has held for the past twelve months. His work has been of inestimable value in establishing and enlarging the Section, which was formed in 1950. His successor in office is Mr. W. Hemer, Associate Member.

MR. C. G. PETTIT

Mr. C. G. Pettit, Member, has been appointed to the position of Assistant Managing Director of The Incandescent Heat Company Limited, Smethwick, the parent Company of the Incandescent Group of Thermal Engineers.

Mr. Pettit joined the Company in 1927 and is well-known in the heavy engineering industry.

MR. LAWRENCE W. ROBSON

Mr. Lawrence W. Robson, Associate, has been appointed Deputy Chairman of Associated British Engineering, Limited, London. Mr. Robson is Joint Chairman of the Joint Committee on Measurement of Productivity.

NEW APPOINTMENTS

Mr. C. E. Barkworth, Member, has been appointed General Manager of Crothers Engineering Ltd., Toronto.

Mr. E. C. R. Barry, Int. Associate Member, has been promoted to the post of Production Manager of his Company, Tannoy Products, Ltd., London.

Mr. R. Gore, Associate Member, has taken up an appointment as Efficiency Engineer with Rolls-Royce, Ltd., East Kilbride Factory.

Mr. S. J. Harley, Member, Chairman of the Coventry Gauge & Tool Co. Ltd., has been elected to the Board and appointed Chairman of the Pitter Gauge & Precision Tool Co. Ltd.

Mr. A. N. I. Pratt, Associate, has taken up an appointment as Chief Buyer for Teddington Controls, Ltd., Merthyr Tydfil.

Mr. R. J. Upcott, Associate Member, is now an Engineer III with the Machine Tool Section (Air Division) of the Ministry of Supply.

Mr. D. B. Vallance, Member, is now Works Manager of Thomas White & Sons, Ltd., Paisley.

Mr. R. J. Woodhams, Associate Member, is leaving for Australia this month in order to take an appointment as Manager of the Australian Division of Sir W. G. Armstrong Whitworth Aircraft, Ltd.

Mr. P. H. F. Burton, Graduate, has taken an appointment as Project Engineer with Handley Page, Ltd., Reading.

Mr. H. J. Richards, Graduate, is now a Production Engineer at R. A. Lister & Co., Ltd., Dursley.

Mr. D. E. Taylor, Graduate, has been appointed Third Assistant Engineer (Mechanical), Generator Construction Department, at the East Midlands Divisional Headquarters of the British Electricity Authority.

Mr. L. Taylor, Graduate, is now employed as Assistant Planning Engineer, Fusarc Ltd., Gateshead.

Mr. D. Treasurer, Graduate, has been transferred to Jones, Tate & Co., Ltd., Bradford, by Dewrance & Co., Ltd., in order to take up liaison duties between the two Companies.

INSTITUTION NOTES

ASSOCIATE MEMBERSHIP EXAMINATION

The Associate Membership Examination of the Institution of Production Engineers will be held from Monday, 18th May, to Saturday, 23rd May, 1953, inclusive.

All applicants must complete the appropriate form of application for Membership and return it to Head Office not later than 1st March, 1953. These forms will be assessed by the Council before applicants are accepted as candidates for the examination. No examination entry form is required.

Application forms, copies of the Examination Regulations, and copies of the 1951 and 1952 Examination Papers (price 2/-), may be obtained from the Head Office of the Institution.

LEICESTER SECTION DINNER

Speaking at the Annual Dinner of the Leicester Section, held on 28th November last at the Grand Hotel, Leicester, Sir Holland Goddard, a Past President of the Machine Tool Trades Association and a prominent industrialist, warned Production Engineers to expect serious competition from Germany. Britain, he said, must strive her utmost to produce better designs at low cost, and above all must build up her overseas connections.

Among the other distinguished guests at the Dinner were the Lord Mayor of Leicester (Alderman Geoffrey Barnett), and the President of the Institution, Sir Cecil Weir, who came from Luxembourg specially to be present.

Supporting Sir Holland Goddard's remarks, Sir Cecil said that no other country in the world was more dependent upon export trade than Britain, and consequently there must be no relaxation in her efforts to expand in this direction.

LONDON SECTION DINNER-DANCE

December 3rd marked the revival of the very fine dinner-dances that were such an outstanding part of the London Section activities until early 1940.

At the request of many members, the Section Committee decided to organise this function in addition to the all-male dinner to be held on 18th February, and the result justified completely the work it involved.

Some three hundred members and their ladies and other guests were received by Mr. Richard Kirchner, Section President, and Mrs. Kirchner at the Savoy Hotel, and from the moment the Reception started until the final break-up at 1 a.m. the activities and obvious enjoyment of all present did not flag for one second.

Receiving the Lord Mayor of Leicester at the Leicester Section Dinner is Sir Cecil Weir, President of the Institution. Included in the group are Sir Holland Goddard (left), Mr. S. Radcliffe, Section President (centre), and Mr. N. A. Cullin, Member (right).

Mr. Robert Hutcheson, Section Hon. Secretary, shares a joke with Mr. Richard Kirchner, Section President, and Mrs. Kirchner, at the London Section Dinner Dance.

The guests of honour were Mr. H. Burke, Chairman of Council, and the Institution Secretary, Mr. W. F. S. Woodford and Mrs. Woodford. Unfortunately, Mrs. Burke was prevented from attending, while Sir Cecil and Lady Weir could not be present owing to the enforced stay of Sir Cecil in Brussels.

In view of the fact that ladies were present, the number of speeches was kept to four and each speaker was allowed five minutes—which was exceeded by none. The toast to the guests was proposed by Mr. A. L. Stuchbery, Past Section President, who welcomed official guests and the guests of members. Mr. Burke replied to this in his very concise and vigorous manner that marks him as an excellent speaker on such occasions. He said that in spite of the very high standard of the Birmingham Section Dinner Dances he was returning to Birmingham full of praise for the evening, and to warn his own Section that they must look to their laurels in view of the extremely high standard of the London Section Dinner Dance.

Mr. W. Opher, in proposing the toast to the London Section President, recalled that Mr. Kirchner and he were boys at school together. He outlined the many years of valuable work that Mr. Kirchner had given to the Institution and wished him every success during his remaining period of office, to which Mr. Kirchner replied.

George Jay's orchestra played light music during dinner and then gave a selection of tunes for dancing. Lucky couples, in novelty dances, who accomplished amusing tasks set by George Jay, were rewarded with prizes presented by Mrs. Kirchner.

The evening concluded with the singing of Auld Lang Syne, and the opinion of everyone present was that the evening had been highly successful in every way and all looked forward to the establishment of this function as an annual event.

FELLOWSHIP IN MANAGEMENT ACCOUNTANCY

The establishment of a Fellowship in Management Accountancy by the Institute of Cost and Works Accountants was recently announced by the President, Mr. S. C. Tyrrell, F.C.W.A., F.I.I.A.

Speaking at a Press Conference, Mr. Tyrrell said that the establishment of this postgraduate qualification was a significant advance in the accounting world, and one of particular interest to directors and shareholders, as the new Fellowship would be the highest qualification obtainable for Management Accountancy in all its aspects.

Until the Council of the I.C.W.A. decided to make this award, no qualification was recognised as indicating that its holder commanded the practical experience and technical knowledge that would fit him for the senior accounting positions in industry.

The first examination for the Fellowship will be held in December, 1953. The Syllabus and full particulars may be obtained on application to The Director, Institute of Cost and Works Accountants, 63, Portland Place, London, W.1.

HAZLETON MEMORIAL LIBRARY

Members are asked to note that the Library will be open between 10 a.m. and 5.30 p.m. from Monday to Friday each week, and from 9.30 a.m. to 12.30 p.m. on Saturdays. Due to Meetings, the full facilities will not be available at the following times during this month :—

Thursday,	12th February	all day.	Tuesday,	17th February	all day.
Tuesday,	24th February	from midday.	Wednesday,	25th February	from 2.30 p.m.

It would be helpful if, in addition to the title, the ***author's name*** *and the classification number could be quoted when borrowing books.*

REVIEWS

942.084 GREAT BRITAIN—History—World War II

British War Production by M. M. Postan. *London, H.M.S.O., and Longmans Green,* 1952. 512 *pages.* £1 12s. 6d.

History of the Second World War, U.K. Civil Series, edited by W. K. Hancock.)

This book emphasises the magnitude of the supply problem of aircraft, guns, tanks, ships, machine tools and all supplies, including labour, required for World War II. It outlines in considerable detail the methods which were taken to meet the changing position as the war expanded from year to year.

If one looks from chapter to chapter, it will be seen by the headings what emergencies had to be taken to meet the various situations. After the Battle of the Atlantic, the change from defence by air to air and land attack is described in a most absorbing way. It is difficult to name any particular part of the book as being more interesting than the other, but the production of radio is one of special interest and so, of course, is the supply of machine tools.

While the book contains all the figures and statistical tables to make the volume of value, it has been put together in such an interesting way as to make enjoyable reading. It is particularly well indexed and it is suggested that it should be liberally used. H.A.C.

331.152 CO-OPERATIVE ADMINISTRATION ; JOINT CONSULTATION

Joint Consultation in British Industry by National Institute of Industrial Psychology, London. *Staples Press, London,* 1952. 276 *pages.* 21/-.

This, the first comprehensive survey of Joint Consultation in Industry, is a Report of the findings of a research team organised by the National Institute of Industrial Psychology, whose terms of reference were derived from the Human Factors Panel of the Committee of Industrial Productivity. Members of the team themselves visited 189 factories and tabulated information received from many others, in response to a comprehensive questionnaire.

After analysing many varied purposes and aims of Joint Consultation, the report deals at some length with the psychological conditions in which it has been found to flourish or fail. Another section is devoted to analysis of committee organisation, composition and procedure, and to problems of reporting back.

The achievements of Joint Consultation, varying from almost complete failure to startling successes in many fields, are covered in a further section. A final important chapter discusses common sources of conflict and varying attitudes towards Joint Consultation.

It is apparent from the Report that industry as a whole is only tinkering with the problem at present: Executives, Trade Union leaders, and elected representatives by reading it, may well be stimulated to examine their own attitudes towards Joint Consultation, so that many more companies will foster a climate in which it will prosper. F.E.M.

002. DOCUMENTATION

" Punched Cards : Their Application to Science and Industry " by Robert S. Casey and James W. Perry. *Reinhold Publishing Corporation, New York (Chapman and Hall, London).* 80/-

The Editors of this symposium, involving some thirty authors, with biographical details, have taken as their main theme the application of punched cards to statistical analysis and evaluation of research and scientific data with a definite bias towards chemical applications. The book in its entirety substantiates the fact that the all-important virtue of punched cards in any form is the ability to sort.

Part One comprises an introduction to the basic principles of numerous systems employing in some form holes punched in cards, but is restricted to equipment manufactured in the U.S.A. British manufacturing machines are referred to in Parts Two and Three, where specific applications are dealt with.

Coding is synonymous with the application of punched cards and this aspect of the subject is also covered.

Finally, the book contains a good bibliography, but still mainly within the more narrow confines of the application of punched cards to science and research, and there are also excellent indices of subjects and authors.

This publication can be described as a reference book which should appear in the libraries of all statisticians and scientists in national and industrial research organisations. F.G.S.E.

ABSTRACTS

519.2 STATISTICS

" Danger Figures for Production Management " by British Institute of Management, London. *The Institute,* 1952. 28 *pages. Chart.* 3s. 6d.

(Management Statistics Series No. 1.)

This booklet is one of a series covering Management Statistics, and deals in a logical sequence with the facts required for the efficient control of Production Management, utilising existing records.

The first stage describes the kind of information required to measure the productivity of the working unit as a guide to efficiency, and the relationship between Productivity and Costs. The various elements of these factors are broken down, and their tabulation for correct presentation to management is shown.

The second stage deals with the causes of lowered efficiency, i.e. the factors causing loss of working time and reduced effectiveness of working, together with the presentation of this information to management.

The final chapters cover the setting of performance standards, and their use in investigating the causes of lowered efficiency covered in the earlier chapters.

The booklet is of particular interest to Works Directors, and Cost Accountants. Students studying Industrial Administration will find it useful.

373.6 COMMERCIAL AND TECHNICAL TRAINING

"Modern Staff Training: A Survey of Training Needs and Methods Today" by F. J. Tickner. *London, University of London Press,* 1952. 159 *pages. Illustrated.* 12s. 6d.

After stressing the need for staff training, the author moves from the small unit to the large organisation, with its Training Centre. The workers' difficulties in the transition period following the Training Centre are stated, and emphasis is placed on those with subsidiary functions, such as canteen staff and gatekeepers. Office staff, being usually in smaller units, receives training on the job, but a plea is made for mobility even in the small office.

The necessary "skills" of Works and Staff Supervisors are given and the use of College and Residential Courses considered. The Urwick Report introduces the chapter on Management Training and the various methods used at Training Centres are detailed and suggestions made for the selection of Training Officers. The book closes with a chapter on advanced training at the various Staff Colleges.

PAPERS RECEIVED

1921: **"The Extrusion of Brass Rod and Section"** by D. J. Broadley.

1922: **"Training Related to Practice in Production Processes"** by E. M. Price.

1923: **"The High Cost of Low Overheads"** by C. H. Starr.

1924: **"Planning for 5 or 250,000 Parts"** by R. E. Copelin.

1926: **"Some Present-Day Trends in Engineering Metrology"** by C. O. Taylerson.

1927: **"American Methods"** by Lt.-Col. Jemmott.

1928: **"Machining to Facilitate the Assembly of Vertical Spindle Pump Shafting"** by J. B. Wilcox.

1929: **"Methods of Achieving More Economical Production"** by E. V. Graham.

1930: **"Some Wider Aspects of Management"** by Sir Ewart Smith.

PERIODICALS CURRENTLY RECEIVED

An alphabetical list of titles, indicating place of publication, and frequency.
The following abbreviations are used:

a.	annual.	**b.m.**	bi-monthly.	**b.w.**	bi-weekly.
f.	fortnightly.	**h.y.**	half-yearly.	**i.**	irregular.
m.	monthly.	**q.**	quarterly.	**s.m.**	semi-monthly.
3p.a.	3 issues per annum.	**w.**	weekly.		

Aero Research Technical Notes. Duxford, Cambridge. **m.**
Aircraft Engineering. London. **m.**
Aircraft Production. London. **m.**
Aluminium Courier. London. **i.**
Aluminium News. Montreal. **m.**
American Machinist. New York. **b.w.**
American Management Association. Manufacturing Management Series. New York. **i.**
Aslib Booklist. London. **m.**
Aslib Information. London. **m.**
Aslib Proceedings. London. **q.**
Association Française des Conseils en Organisation Scientifique. [Bulletin] Mensuel. Paris.
Austin Technical News. Birmingham. **f.**
Australasian Engineer. Sydney. **m.**
Automobile Engineer. London. **m.**
B.S.F.A. Abstracts. Sheffield. **b.m.**
B.S.F.A. Bulletin. Sheffield. **i.**
Ball Bearing Journal. Luton, Beds. **q.**
Beama Journal. London. **m.**
Bibliographia Scientiae Naturalis Helvetica. Berne. **a.**
Bibliography of Industrial Diamond Applications. London. **m.**
The Bonderizer. Brentford, Middx. **m.**
British Cast Iron Research Association. Bulletin and Foundry Abstracts. Birmingham. **b.m.**
British Machine Tool Engineering. London. **q.**
British Management Review. London. **q.**
British Non-Ferrous Metals Research Association. Bulletin. London. **m.**
British Packer. London. **m.**
British Plastics. London. **m.**
British Standards Institution London Standard Specifications. **i.**
Monthly Information Sheet.
Yearbook.
C.N.O.F. Paris. **m.**
Centre de Documentation Sidérurgique.
Bulletin Analytique. Paris. **m.**
Circulaire d'Informations Techniques. Edition Commune. Paris. **m.**
Cost Accountant. London. **m.**
The Director. London. **m.**
Documentation Mécanique. Paris. **m.**
Doelmatig Bedrijfsbeheer. Alphen aan den Rijn. **m.**
Ecole d'Organisation Scientifique du Travail. Trait d'Union de l'Association Amicale des Anciens Elèves. Paris. **m.**
Economist. London. **w.**
Electric Tool User. London. **i.**
Electrical Manufacturer. London. **b.m.**
Electrical Review. London. **w.**
Electrodepositors' Technical Society. Journal. London. **i.**
Electronic Application Bulletin. Eindhoven, Holland. **m.**
Elliott Journal. London. **h.y.**
Engineer. London. **w.**
Engineer & Foundryman. Johannesburg. **m.**
Engineering. London. **w.**
Engineering Bulletin. Lafayette, Ind. **b.m.**
Engineering Experiment Station News. Columbus, Ohio. **b.m.**
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Engineering Industries Bulletin. London. **m.**
Engineering Journal. Montreal. **m.**
Engineers' Digest. London. **m.**
English Electric Journal. Stafford. **q.**
Esso Oilways. London. **q.**
Etude du Travail. Paris. **m.**
Factory Management and Maintenance. New York. **m.**
Factory Manager. London. **m.**
Fasteners. Cleveland, Ohio. **i.**
Foundry Trade Journal. London. **w.**
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Government Publications Consolidated List. London. **a.**
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Index Aeronauticus. London. **m.**
Indian & Eastern Engineer. Calcutta. **m.**
Industrial Welfare & Personnel Management. London. **b.m.**
Informes de la Construccion. Madrid. **m.**
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Institute of Metal Finishing, incorporating Electrodepositors' Technical Society. Bulletin. London. **q.**
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Institution of Heating and Ventilating Engineers. Journal. London. **m.**
Institution of Mechanical Engineers. Journal. London. **m.**
Proceedings. London. **a.**
Institution of Mechanical Engineers—*Automobile Division*. Proceedings. London. **a.**
Institution of Production Engineers. Journal. London. **m.**
Instituto Tecnico de la Construccion y del Cemento. Monographs. Madrid. **i.**
Instrument Engineer. Luton. **h.y.**
Irish Engineering Journal. Dublin. **m.**
Iron Age. New York. **w.**
Iron and Steel Institute. Journal. London. **m.**
Journal of Documentation. London. **q.**
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Light Metals Bulletin. London. **s.m.**
Lubrication. New York. **m.**
Machine and Tool Blue Book. Wheaton, Ill. **m.**
Machine Design. Cleveland, Ohio. **m.**
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Magnesium Review and Abstracts. Manchester. **i.**
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Mass Production. London. **m.**
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Modern Machine Shop. Cincinnati, Ohio. **m.**
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Motion Economy. Cheadle, Cheshire. **h.y.**
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New Methods and Machines. London. **m.**
New Technical Books. New York. **b.m.**
New Zealand Engineering. Wellington, N.Z. **m.**
Nickel Bulletin. London. **m.**
Occupational Psychology. London. **q.**
Office Management Association. Journal. London. **m.**
Ohio State University Studies, Engineering Series. Columbus, Ohio. **q.**
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Oil Lifestream of Progress. New York. **q.**
Operational Research Quarterly. London.
Pera Bulletin. Melton Mowbray, Leics. **m.**
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Philip's Technical Review. Eindhoven, Holland. **m.**
Physics Abstracts. London. **m.**
Polish Technical Abstracts. Warsaw. **i.**
Power Transmission. London. **m.**
Product Engineering. Albany, N.Y. **m.**
Product Finishing. London. **m.**
Produttivita. Milan. **m.**
Refa Nachrichten. Darmstadt. **q.**
Report. Dorking. **i.**
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Revista de Ciencia Aplicada. Madrid. **b.m.**
Revue Generale des Sciences Appliquées. Brussels. **b.m.**
Rivista di Meccanica. Milan. **f.**
Rotol Digest. Gloucester. **m.**
Royal Aeronautical Society. Journal. London. **m.**
Royal Institute of Technology. Transactions. Stockholm. **i.**
Rubber Developments. London. **q.**
Science & Engineering. Calcutta. **b.m.**
Scientific Lubrication. Wellington, Salop. **m.**
Scope. London. **m.**
Screw Machine Engineering. Rochester, N.Y. **m.**
Sheet and Strip Metal Users' Technical Association. Annual Proceedings. London.
Sheet Metal Industries. London. **m.**
Shell Magazine. London. **m.**
The Supervisor. Birmingham. **m.**
Swiss Technics. Lausanne. **3 p.a.**
Target. London. **m.**
Tijdschrift voor Efficientie en Documentatie. 's-Gravenhage, Holland. **m.**
Time and Motion Study. London. **m.**
Times Review of Industry. London. **m.**
Tool Engineer. Milwaukee, Wis. **m.**
Tool Trade. London. m.
Toolmaker & Precision Engineer. London. **m.**
Torque. London. **q.**
University of Illinois. Bulletin. Urbana, Ill. **i.**
V-Belt Journal. Hull. **q.**
Vickers' Overseas News. London. **q.**
Welding and Metal Fabrication. London. **m.**
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Whitaker's Cumulative Book List. London. **q.**
Woman Engineer. London. **i.**
Works Management. London. **m.**
Z.D.A. Abstracts. Oxford. **m.**
Zinc Bulletin. Oxford. **i.**

Issue of Journal

Owing to the fact that output has to be adjusted to meet requirements, and in order to avoid carrying heavy stocks, it has been decided that the Journal will only be issued to new Members from the date they join the Institution.

Corrigendum

W. T. Flather, Ltd., of Sheffield, have asked that attention be drawn to a descriptive error in the paper "Modern Trends in the Selection of Steels," published in the December, 1952, issue of the Journal.

On page 603, the word "frames" (third line, second paragraph) should read "'lenses."

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1952 / 53

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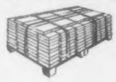

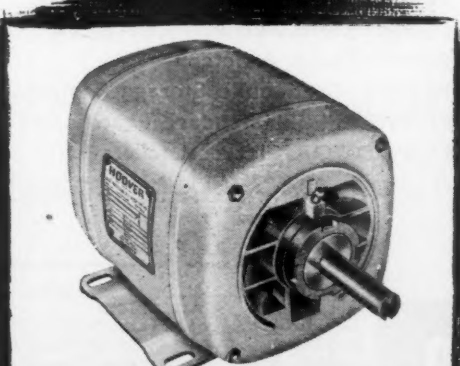
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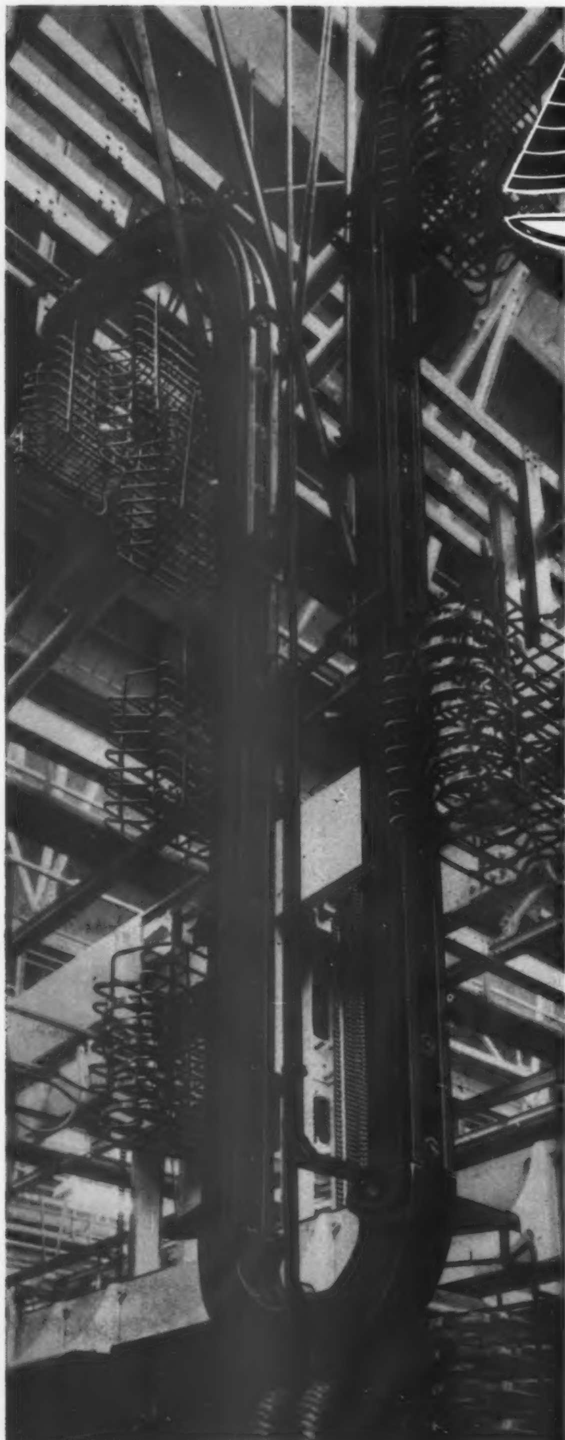

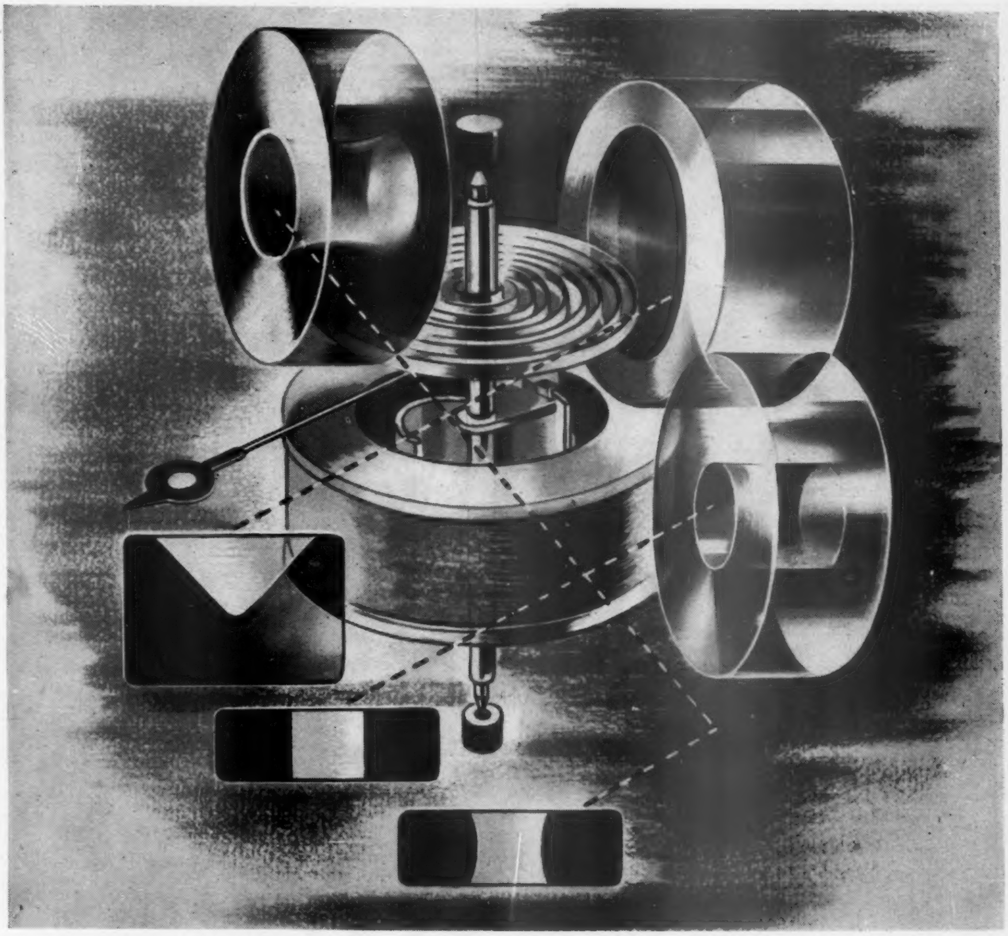


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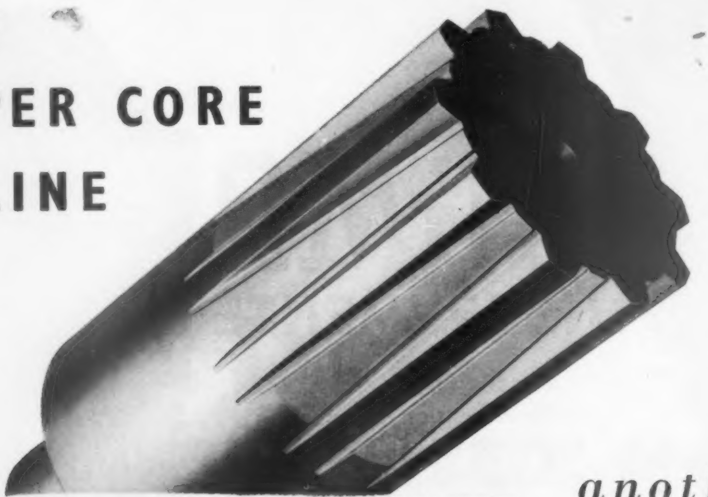

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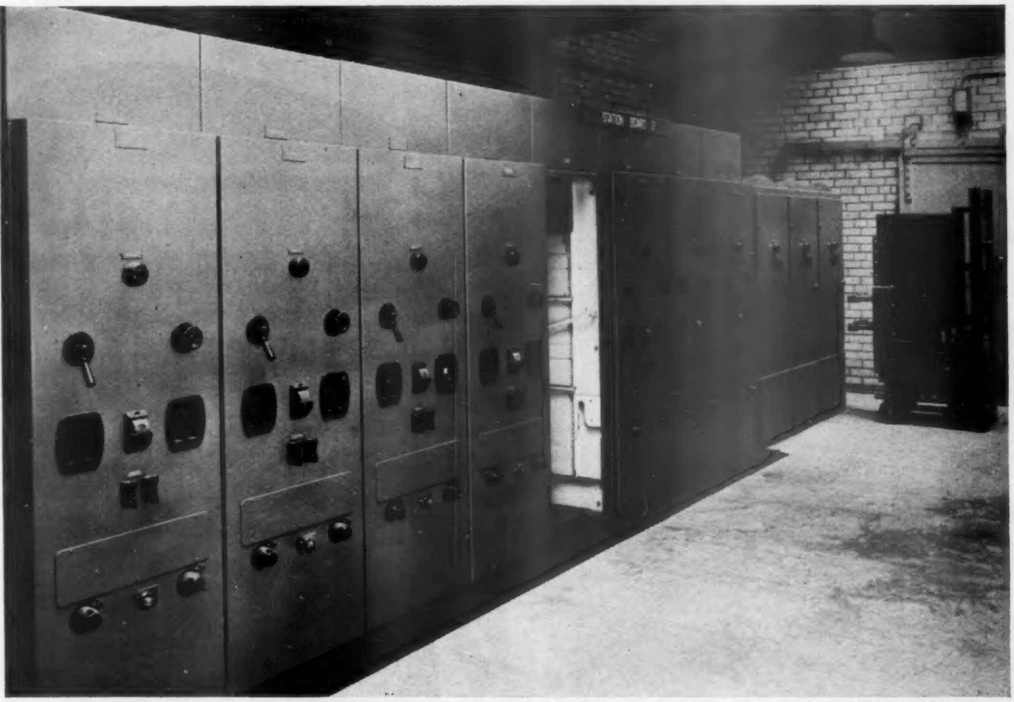

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Institution Conference, Harrogate 25th to 28th June, 1953.

PRELIMINARY NOTICE

An Institution Conference will be held at Harrogate from 25th to 28th June, 1953 (i.e. the nights of 25th, 26th and 27th June for booking hotel accommodation). The arrangements and programme planning will be similar to the Conference which was held at Harrogate in June, 1951, and full details will be published later.

Members are asked to notify the Secretary if it is their intention to be present at the Conference and a form is enclosed for this purpose. Members may bring guests. Ladies will be welcome, and special arrangements will be made for their entertainment.

Members who wish to attend should make an early reservation of hotel accommodation. A list of Harrogate hotels will be sent to all members who notify the Secretary. An application form appears on page 5 of this Supplement.

Conference Charges:—

Members' Conference Fee	30/-	Ladies Guests Fee	10/-
Gentlemen Guests Fee	30/-	Conference Banquet Tickets	25/- each

SIR ALFRED HERBERT LECTURE, 1953

Council of the Institution have great pleasure in announcing that Sir John Cockcroft, C.B.E., Ph.D., M.A., M.Sc (Tech). D.Sc (h.c.) Oxford, F.R.S., Hon.Ll.D. (Toronto), M.I.E.E., Director of the Atomic Energy Research Establishment of the Ministry of Supply at Harwell, has accepted the Institution's invitation to present The Sir Alfred Herbert Lecture, 1953. He has chosen as his subject:

"Industrial Applications of Atomic Energy".

The meeting will be held in OXFORD on 24th July, 1953. Full details will be circulated to all members in due course. In the meantime, will you please note this important date for your diary.

INSTITUTION OF MECHANICAL ENGINEERS—JAMES CLAYTON LECTURE

Mr. James R. Bright will present a lecture on "Materials Handling" at the Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1., on 17th April, 1953, at 5.30 p.m. Refreshments will be available.

Members of the Institution of Production Engineers have been invited to attend this lecture. Admission will be by ticket only, a limited number of which are available from the Secretary, 36, Portman Square, London, W.1.

B.R.A. HOMES LTD.

In response to the President's Appeal, the following companies have sent donations to the British Rheumatic Association:

Austin Motor Co. Ltd.	£500	General Motors, Ltd.	£500
Morris Motors, Ltd.	£500	Rubery Owen & Co. Ltd.	£500

Production Appointments appears on page 3.

MEETINGS

This notice is circulated in place of members' lecture tickets which have been discontinued. Visitors' tickets may be obtained from Section Hon. Secretaries.

February 7th to 28th, 1953

NOTE: The HAZLETON MEMORIAL LIBRARY will remain open until 7.15 p.m., on the nights when London Graduate Lecture Meetings are being held, for the convenience of members attending the meeting.

BIRMINGHAM **FEBRUARY 7th**
The Botanical Gardens, Edgbaston.
Buffet Dance.

BIRMINGHAM **7 p.m. FEBRUARY 18th**
The James Watt Memorial Institute, Great Charles Street, Birmingham.
"The Application of Hydraulics to Profile Milling Machines" by S. C. Fenton, Esq.

BIRMINGHAM GRADUATE SECTION **7 p.m. FEBRUARY 10th**
The James Watt Memorial Institute, Great Charles Street, Birmingham.
"The Future Development of Machine Tool Design" by J. W. Wilkinson.

COVENTRY **7 p.m. FEBRUARY 17th**
The Geisha Cafe, Hertford Road, Coventry.
"Standardisation" by Dr. H. E. Merritt, M.B.E., D.Sc., M.I.Mech.E.

COVENTRY GRADUATE **7.30 p.m. FEBRUARY 17th**
The Hare and Squirrel Hotel, Cow Lane, Coventry.
"Douglas D. Davis Award" (Part B).

COVENTRY GRADUATE **7.30 p.m. FEBRUARY 26th**
The Technical College (Room A.5), Coventry.
Joint Meeting with the Institute of Industrial Administration.
"Management Forum" with A. W. Weeks, M.I.Mech.E., and I. L. Jones, J.P.

CORNWALL 7.15 p.m. **FEBRUARY 25th**
The Cornwall Technical College, Trevenson Park, Pool, Redruth.
Local Discussion on "Incentives".

DERBY 7 p.m. **FEBRUARY 16th**
The College of Art, Green Lane, Derby.
"Work Study" by R. M. Currie.

DUNDEE 7.30 p.m. **FEBRUARY 11th**
The Imperial Hotel, Arbroath.
Joint Meeting with Institute of British Foundry men N.E. Scottish Section, and the Institute of Engineering Inspection, Dundee Section.
"The Reclamation of Porous Castings by Impregnation" by P. J. Young.

DUNDEE **FEBRUARY 26th**
Works Visit to John Lang and Co. Ltd., Dundee.

EASTERN COUNTIES 7.30 p.m. **FEBRUARY 13th**
The Public Library, Ipswich.
"The Application of High Frequency Induction" by E. H. L. Cooper, M.I.Mech.E., M.I.E.E.

EDINBURGH 7.30 p.m. **FEBRUARY 18th**
The North British Station Hotel, Princes Street, Edinburgh.
"Planning for Production Incorporating Cost Control" by C. W. Higgins. Joint Meeting with the Institute of Cost and Works Accountants.

GLASGOW 7.30 p.m. **FEBRUARY 19th**
The Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2.
"American Valve Industry" by J. Wark, A.M.I.Prod.E.

HALIFAX 7.15 p.m. **FEBRUARY 10th**
The White Swan Hotel, Halifax.
"The Manufacture of Ball and Roller Bearings" by R. K. Allan, A.M.I.Mech.E., M.I.Prod.E.

HALIFAX GRADUATE 7.15 p.m. **FEBRUARY 18th**
The White Swan Hotel, Halifax.
"Work Study as an Aid to Productivity" by R. S. Cracknell, Grad.I.Prod.E., also "The Responsibilities of a Production Engineer". (Report of Graduate Weekend School).

LEICESTER 7 p.m. **FEBRUARY 5th**
Place of Meeting will be notified.
Address by F. Hayday, National Industrial Officer of the National Union of General and Municipal Workers, on "Joint Consultative Machinery at Factory Level".

LINCOLN 7.30 p.m. **FEBRUARY 24th**
The Technical College, Gainsborough.
Film Show—"Prelude to Power"; Conveyors as your Servants"; "Out of the Dark".

LIVERPOOL 7.30 p.m. **FEBRUARY 4th**
Radiant House, Bold Street, Liverpool.
"The Function of Rate Fixing in Workshop Practice" by V. Eaves, A.M.I.Prod.E.

LONDON 7 p.m. **FEBRUARY 12th**
The Royal Empire Society, Northumberland Avenue, W.C.2.
"Factory Services" by R. E. Leakey, M.I.Prod.E.

LONDON **FEBRUARY 18th**
Annual Dinner at the Connaught Rooms, London, W.C.

LONDON GRADUATE 7.15 p.m. **FEBRUARY 17th**
The Institution of Production Engineers, 36, Portman Square, London, W.1.
"High Productivity—The Key Features of American Production Management" by L. J. S. Saunders, Grad.I.Prod.E.

LONDON GRADUATE **FEBRUARY 4th**
Works Visit to Barnet, Ensign, Ross, Ltd.

LUTON SENIOR & GRADUATE
7.15 p.m. **FEBRUARY 24th**
The Small Assembly Room, Town Hall, Luton, Beds.
"Future Prospects of the Production Engineer" by W. C. Puckey, M.I.Prod.E., F.I.I.A.

MANCHESTER 7.15 p.m. **FEBRUARY 23rd**
Reynolds Hall, The College of Technology, Sackville Street, Manchester, 1.
"Pressed Metal" by S. Cadman.

MANCHESTER GRADUATE
6.45 p.m. **FEBRUARY 18th**
The Reynolds Hall, (Room C.3), College of Technology, Sackville Street, Manchester, 1.
"Industrial Plastics and their Applications" by A. Thompson, B.Sc. Illustrated.

MANCHESTER GRADUATE
10 a.m. **FEBRUARY 21st**
Works Visit to Sir James Farmer Norton & Co. Ltd., Adelphi Iron Works, Salford, 3.

NORTH EASTERN 7 p.m. **FEBRUARY 16th**
The North of England Institute of Mining and Mechanical Engineers, Neville Hall, Westgate Road, Newcastle-upon-Tyne.
"Some Problems Associated with the Manufacture of Large Turbo-Alternators" by J. Henderson, A.M.I.Mech.E., M.I.Prod.E., and J. W. Taylor, Assoc.I.E.E., A.M.I.Prod.E.

NORTH EASTERN GRADUATE
7 p.m. **FEBRUARY 27th**
The Northern Gas Board Showrooms, Grainger Street, Newcastle-on-Tyne.
"Welding as an Aid to Economic Production" by J. Felton.

NORTHERN IRELAND 7.30 p.m. **FEBRUARY 19th**
The College of Technology, Belfast.
Presidential Address by Sir Cecil Weir, K.C.M.G., K.B.E., M.C., D.L.

NORWICH SUB-SECTION 7.30 p.m. **FEBRUARY 12th**
The Technical Institute, Great Yarmouth.
Film "Hard Metal" and Discussion.

NOTTINGHAM 7 p.m. **FEBRUARY 4th**
The Victoria Station Hotel, Milton Street, Nottingham.
"Developments in Centreless Grinding Technique" by A. Scrivener, M.C., M.Inst.B.E.

OXFORD SUB-SECTION 2 p.m. **FEBRUARY 3rd**
Works Visit to the Northern Aluminium Company Ltd., Banbury, Oxon.

OXFORD SUB-SECTION 7.15 p.m. **FEBRUARY 17th**
Morris Motors Ltd., Apprentice School, Hollow Way, Cowley, Oxford.
"Colour Schemes in Industry" by S. A. Wood.

PRESTON 7.15 p.m. **FEBRUARY 11th**
The Crown Hotel, Market Place, Blackburn.
"Ex Minimo Maximum (The Engineering of Standardisation)" by E. G. Brisch, M.I.Mech.E., M.I.Prod.E.

READING 7.15 p.m. **FEBRUARY 5th**
The Canteen, Transport Equipment (Thornycroft) Ltd., Worting Road, Basingstoke.
"Ball and Roller Bearing Manufacture and Application" by R. K. Allan, A.M.I.Mech.E., M.I.Prod.E.

ROCHESTER & DISTRICT 7.30 p.m. **FEBRUARY 12th**
The Rotary Room, Sun Hotel, Chatham
"Practical Gear Production" by L. Westley-Smith, M.I.ProdE.. M.Inst.B.E.

SHEFFIELD 6.30 p.m. **FEBRUARY 9th**
The Royal Victoria Station Hotel, Sheffield.
"Modern Cold Rolling Mills" by G. W. Ashton.

SHEFFIELD 6.30 p.m. **FEBRUARY 23rd**
The Royal Victoria Station Hotel, Sheffield.

SHEFFIELD GRADUATE 6.30 p.m. **FEBRUARY 17th**
The Royal Victoria Station Hotel, Sheffield.
Informal Discussion on Production Problems.

SHREWSBURY 7.30 p.m. **FEBRUARY 25th**
The Walker Technical College, Cakengates, Salop.
"Gear Cutting Procedure" by H. Pearson.

SOUTHERN 7 p.m. **FEBRUARY 19th**
The Polygon Hotel, Southampton.
"Some Thoughts on Progressive Press Tools" by G. V. Bevan.

SOUTH ESSEX SUB-SECTION
7.30 p.m. **FEBRUARY 18th**
Chelmsford Mid Essex Technical College.
"Resistance Welding in America" by G. Cubitt Smith, M.Met.E., D.L.C., G.I.Mech.E., Grad.I.Prod.E.

STOKE-ON-TRENT SUB-SECTION **7.30 p.m. FEBRUARY 20th**
The Town Hall, Hanley, Stoke-on-Trent.
"Efficient Production Methods Applied to Iron Founding" by G. W. Nicholls, A.M.I.Prod.E., M.I.B.F.

SOUTH WALES AND MONMOUTHSHIRE **6.45 p.m. FEBRUARY 26th**
The South Wales Institute of Engineers, Park Place, Cardiff.
"How Production Engineers can be helped by the Metallurgist" by J. D. Jevons, Ph.D., B.Sc., F.R.I.C., F.I.M.

WESTERN **7.15 p.m. FEBRUARY 18th**
The Marlborough Room, Grand Hoted, Bristol.
"The Impact of the Gas Turbine Aero Engine Production Methods" by D. A. Farnie, B.Sc., F.R.Ae.S., M.I.Prod.E.

WESTERN GRADUATE **7.30 p.m. FEBRUARY 9th**
The Grand Hotel, Broad Street, Bristol.
Brains Trust with H. Teasdale, M.I.Prod.E. as Chairman.

WESTERN GRADUATE **7.30 p.m. FEBRUARY 26th**
The Grand Hotel, Broad Street, Bristol.
"Layout for Batch Production" by B. C. Harrison, M.I.Prod.E.

WEST WALES **7.30 p.m. FEBRUARY 6th**
The Central Library, Alexandra Road, Swansea.
"Methods of Achieving More Economic Production with the Emphasis on the Importance of the Labour Element" by R. W. Mann, M.I.Prod.E., M.I.E.E., M.I.Min.E.

WOLVERHAMPTON **7.15 p.m. FEBRUARY 25th**
The Wolverhampton and Staffordshire Technical College.
"General Impressions of Automobile Production Methods gained during a recent visit to the U.S.A." by D. Burgess, M.I.Prod.E.

WOLVERHAMPTON GRADUATE **7.30 p.m. FEBRUARY 19th**
The Victoria Hotel, Lichfield Street, Wolverhampton.
"Costing for the Small Engineering Firms" by J. H. Smith, F.S.A., A.F.C.I.S.

YORKSHIRE **7 p.m. FEBRUARY 9th**
The Hotel Metropole, King Street, Leeds.
"The Production of Diesel Engine Components" by A. E. Groocock, A.M.I.Prod.E.

YORKSHIRE GRADUATE **2.30 p.m. FEBRUARY 7th**
The Great Northern Hotel, Leeds.
"Graduate Papers" by W. F. S. Woodford and "Deep Drawing and Pressing of Stainless Steel" by A. C. Midgley, Grad.I.Prod.E. (Short Paper for President's Prize).

YORKSHIRE GRADUATE **2.30 p.m. FEBRUARY 28th**
The Great Northern Hotel, Leeds.
"Production of Plastic Injection Moulding and Moulds" by N. B. Miller, Grad.I.Prod.E., and "Younger Outlook on Industry" by J. Wylde, Grad.I.Prod.E.

MARCH 4th to 6th, 1953

COVENTRY **7 p.m. MARCH 4th**
The Church House, Church Street, Rugby.
"The Manufacture of Components from Powdered Metals" by W. D. Jones, M.Eng., Ph.D., F.I.M.

EDINBURGH **7.30 p.m. MARCH 4th**
The North British Station Hotel, Princes Street, Edinburgh.
"Jottings from a Designer's Notebook" by J. A. Horne.

GLASGOW **7.30 p.m. MARCH 5th**
The Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2.
Annual General Meeting and Open Discussion on "The Possibilities of Radial Drilling" led by M. C. Timbury, M.I.Prod.E.

LEICESTER **7 p.m. MARCH 5th**
The Windsor Room, Bell Hotel, Leicester.
Annual General Meeting and Film "Right on Time" (presented by Mr. Marshall of Smith's English Clocks Ltd.).

LONDON **7 p.m. MARCH 5th**
The Old Ship Hotel Assembly Rooms, Brighton.
"Measurements in Gear Manufacture" by R. D. B. Stone.

LONDON GRADUATE **MARCH 5th**
Works Visit to Decca (Radio and Television).

NORWICH SUB-SECTION **7.40 p.m. MARCH 4th**
The Suckling Hall, St. Andrews Plain, Norwich.
"Further Thoughts" (Speaker's choice) by E. C. Gordon England, F.R.Ae.S., M.I.Prod.E.

NOTTINGHAM **7 p.m. MARCH 4th**
The Victoria Station Hotel, Milton Street, Nottingham.
Annual General Meeting to be followed by a film.

READING **7.15 p.m. MARCH 5th**
The Great Western Hotel, Reading.
"British Watch and Clock Production" by R. Lenoir, F.B.H.I.

SOUTHERN **7 p.m. MARCH 6th**
The Polygon Hotel, Southampton.
Annual General Meeting.

WEST WALES **7.30 p.m. MARCH 6th**
The Central Library, Alexandra Road, Swansea.
"The Development of Sheet and Tinplate Mills—The Function of Lubricants and Process Oils" by W. Williams, A.M.I.Prod.E., A.M.I.Mech.E., M.S.W.I.E.

PRODUCTION APPOINTMENTS

BULLETIN No. 30

This bulletin is circulated to all members of the Institution monthly as near as possible to the first of the month. Firms or organisations wishing to insert notices in the bulletin should communicate with the Secretary at 36, Portman Square, London, W.1.

The last date for receiving material for insertions in the following month's bulletin is the 20th of each month.

The fee per insertion of up to 100 words is now £3 3s., and over 100 words £5 5s. No charge is made to firms affiliated to the Institution, Technical Colleges Universities and similar organisations.

Advertisers are advised that better response is likely if, in addition to essential qualifications, the following information is given:—

(*a*) Location of appointment; (*b*) Status in the organisation and scope of promotion. (*c*) Salary range and age range.

Advertisers are asked to advise the Institution when vacant appointments are filled. The Institution reserves the right to refuse or withdraw any announcement and also to make any alteration in the wording to ensure conformity with Institution standards.

Members interested in the following appointments should make application in accordance with the terms of notice. No correspondence can be undertaken by the Secretary other than the forwarding of replies to Box Nos.

Senior and Junior Jig and Tool Draughtsmen required by Transport Equipment (Thornycroft) Ltd., Basingstoke, Hants., for tooling vehicle chassis and engine components. Permanent and pensionable positions for the right men.

Machine Tool Designer required by manufacturers of single spindle bar automatics. North Midlands area. Attractive position for man with ability and initiative backed by sound workshop experience. Good remuneration and scope for advancement for first-class applicant. Give precise details of previous experience and age. Box No. 519, I.Prod.E., 36, Portman Square, London, W.1.

Creative Designer required by old-established Birmingham firm manufacturing widely known branded light engineering products and leather and fabric goods, to take charge of the department responsible for the design of the Company's products. Excellent opportunity for man with inventive ability. Commencing salary £850 to £950 — pension scheme. Applications giving age, full particulars of education, previous experience and qualifications for the post to be sent for the personal attention of the General Works Manager, Box No. 520, I.Prod.E., 36, Portman Square, London, W.1.

Production Engineer required, with experience of both rate fixing and methods study, for light engineering works on Merseyside. Excellent prospects — housing priority. Pension fund in operation. Write giving details of age, experience, and salary required to Box No. 521, I.Prod.E., 36, Portman Square, London, W.1.

Production Design Engineer required for analysis of design for quantity production of precision instruments. Applicants must have had responsible experience in the design of intricate mechanisms and in addition possess a thorough knowledge of modern manufacturing facilities. This is a senior position and an engineering degree or Institution membership, plus indentured apprenticeship and wide workshop experience, is essential. Salary commensurate. Pension scheme. Write to Personnel Manager, Sperry Gyroscope Co. Ltd., Great West Road, Brentford, Middlesex.

Senior Methods Engineer required to fill important position ; salary commensurate. Essential to have at least H.N.C., indentured apprenticeship, and extensive shop experience, and to be accustomed to laying out complete products for quantity production, including all aspects of processes and tools in field of precision instrument manufacture. Must also have experience and ability to revise drawings where necessary to meet needs of economical production. Pension scheme. Write to Personnel Manager, Sperry Gyroscope Co. Ltd., Great West Road, Brentford, Middlesex.

Factory Manager required for subsidiary Company at Ruislip engaged on production of super-priority telecommunications and radar equipment. Practical and administrative experience in the radio industry in a capacity embracing responsibility for tooling, machining and assembly is essential, and applicants must possess organising ability and drive to carry out a large and varied production programme. Applications giving details of qualifications, experience and salary required may be addressed in confidence to the Personnel Manager, Murphy Radio Limited, Welwyn Garden City, Herts.

Executive Trainees. Field Aircraft Services, Ltd., offer an exceptional opportunity to young men who aspire to Higher Management. Successful candidates will receive a thorough training in most aspects of Aircraft engineering, including component production, complete aircraft overhaul and conversion, complete engine overhaul, and instruments and accessories, etc., with an ultimate view to appointment to managerial positions. Applicants, who must be in possession of an engineering degree or the minimum requirement of the Higher National Certificate, are invited to submit comprehensive details of age, education, experience, etc., in writing to Personnel Officer, Field Aircraft Services, Ltd., Croydon Airport, Surrey.

Tool Designer required for appointment with our Australian Company at Adelaide. Applicants should have wide practical experience of tool design for the production of motor body panels and allied steel presswork. Only first-class men will be considered. Application to be made in writing, with details of education, experience and positions held, to Personnel Officer, Rubery Owen & Co. Ltd., Darlaston, S. Staffs.

Graduate Engineer having a first or second class honours degree in Mechanical Engineering is required for work concerned with research and development of production methods. Excellent prospects for successful applicant. Superannuation scheme in operation. Send full particulars including salary required to Box No. 522, I.Prod.E., 36, Portman Square, London, W.1.

Engineers. Applications are invited from engineers for progressive positions in an industrial organisation in the East Midlands. Applicants should possess a degree or Higher National Certificate in Mechanical Engineering. There are excellent prospects of advancement for successful applicants. Commencing salary commensurate with experience and qualifications ; superannuation scheme in operation. Apply Box No. 523, I.Prod.E., 36, Portman Square, London, W.1.

Planning and Estimating Engineer for electronic equipment. Qualification : H.N.C. in Mechanical Engineering and workshop training in light engineering.

Senior Tool Designer having degree and practical experience of all types of tool design, including deep drawing. Pension and Benevolent Scheme in operation. Houses will be available later for successful applicants for the above vacancies. Apply giving full particulars, including salary required, to Personnel Officer, Airmec Limited, High Wycombe, Bucks.

Production Engineer required. Higher National Certificate standard, with experience in tool-making, drawing office and factory production methods. Excellent opportunity for young man in expanding North London business. Apply in writing, giving full details of age, experience and salary required to Box No. 524, I.Prod.E., 36, Portman Square, London, W.1.

Senior Tool Designer. The Villiers Engineering Company, Ltd., Marston Road, Wolverhampton, manufacturers of world-famous small internal combustion engines, have a vacancy for a Senior Tool Designer. Applicants must have had extensive experience in design of specialised Jigs, Fixtures, and equipment for mass production work. Higher National Certificate in Production Engineering essential. The position offered is permanent and progressive and carries superannuation. Apply in confidence to the Personnel Manager at the above address.

Ratefixer required for modern machine and erecting shops, London, S.W., manufacturing medium to large high-grade equipment of international repute for export. Pensionable position with good prospects. Commence £550. Masson Scott & Co. Ltd., Riverside Road, Summerstown, London, S.W.17.

Methods Engineer for electronic manufacturers in North London. Applicants should have served an apprenticeship and should have had at least seven years' experience in Production Engineering, with an up-to-date knowledge of production methods and techniques. Minimum age 32 years preferred ; member of I.Prod.E. Initiative and ideas for producing new and cheaper methods into manufacturing and assembly essential. Write stating present salary and full particulars to Box No. 525, I.Prod.E., 36, Portman Square, London, W.1.

Chief Process Engineer required to organise and supervise the work of the planning and process departments in large medium/heavy Engineering Works in Glasgow. Applicants must be experienced planning engineers with a sound knowledge of modern production methods covering the following processes : all types of machines, fitting, sub-assembly, erection, plating and welding. Technical qualifications to H.N.C. standard. Only first-class men prepared to take responsibility need apply. Box No. 526, I.Prod.E., 36, Portman Square, London, W.1.

Assistant Chief Work Study Engineer required by light engineering firm in North Wales, manufacturing a wide range of products, to control methods improvements, time study, ratefixing and estimating. The applicant should be experienced in all aspects of work study, and be a capable administrator and experienced in negotiating piecework prices with operatives. Salary £750/£900 per annum. A house may be available, but in any case full assistance will be given by the Company in obtaining suitable accommodation. An assurance scheme is in operation. Write giving qualifications, experience, age, etc., and earliest starting date if successful to Box No. 527, I.Prod.E., 36, Portman Square, London, W.1.

Engineer. Ministry of Supply required Engineer at Chertsey, Surrey, to supervise design and prototype production of special purpose vehicle bodies. Prepare specifications to meet Service requirements and negotiate with coach and body building industry. Qualifications: British, of British parentage; apprenticeship in body building industry; Corp. Mem. of Institution of Civil, Mechanical, or Electrical Engineers, or exempting qualifications. Membership of Inst. of Body Engineers or Inst. of British Carriage and Auto. Manufacturers an advantage. Experience in design and manufacture of special purpose bodies. Salary: Within £927/£1,218 p.a. Appointment unestablished, but opportunities occur for established pensionable posts. Application forms from M.O.L.N.S., Technical and Scientific Register (K), Almack House, 26, King Street, London, S.W.1, quoting Ref. C.7/53A. Closing date: 14.2.53.

Time Study Engineers. Applications are invited for positions of Time Study Engineers on the quantity production of I.C. engines. These positions are of special interest in that the successful applicants will take part in the installation of an efficiency control system after deletion of piecework. Preferred qualifications: full apprenticeship, experience in the automobile industry, and a minimum qualification of Ordinary National Certificate. All applications should state age, experience in chronological order, and salary required. Apply Personnel Manager, Box No. 528, I.Prod.E., 36, Portman Square, London, W.1.

Experience Practical Engineer required to start and be responsible for a new Department for the machining of aircraft details to a high finish and very fine limits in small and large batches. The Plant will include the following: Herbert No. 7 and 9 Combination Turret Lathes; Capstan Lathes; Centre Lathes; Universal Milling Machines; Pantograph Milling Machines; Universal Grinding Machines; Internal Grinding Machines; Surface Grinding Machines; Radial Drilling Machines. Applicant must have had at least ten years' experience on this type of work, and if satisfactory after a trial period will be given opportunity to rent a house or flat. Apply in writing, giving full details of experience, to Alford & Alder (Engineers) Ltd., Deacon Street, Walworth, S.E.17.

Draughtsman required for detail and development work on petroleum marketing equipment. Desired qualifications are: practical engineering experience, H.N.C. in Mechanical or Production Engineering, and drawing office experience. Added advantage would be knowledge of tooling and hydraulics. The Company, at present situated in Croydon, will move to the Margate area towards end 1953, where a new factory will be established and houses will be available for members moving with the Company. The Company, which has world-wide connections, offers very good prospects to the right man. Starting salary according to age and experience. Please write, giving full details, to Box No. 529, I.Prod.E., 36, Portman Square, London, W.1.

Chief Draughtsman required immediately to take charge of modern and well-equipped Drawing Office, engaged in interesting specialised work in connection with the development and execution of a wide variety of mechanical handling schemes. The appointment is considered vital to Company's future plans for considerable expansion of activities. Age 35/45 preferred. Minimum technical qualifications A.M.I.Mech.E., or equivalent. The working conditions are congenial and the post will offer permanency with opportunities of progress. Life insurance and pension scheme. Only first-class men should apply. Applications, which will be treated in confidence and should give age and full particulars of experience, should be addressed to The Chief Engineer, J. Collis & Sons, Ltd., Regent Square, Gray's Inn Road, London, W.C.1.

Chief Engineer required to take charge of mechanical, electrical and building services in seven factories, located in Northamptonshire, controlled by Company manufacturing leather and boot and shoe components. Primary qualifications are a progressive outlook, combined with resource and ingenuity; first-class leadership; and good administrative experience. Age range approximately 35/45. Excellent prospects for a man with ideas and the ability to put them into practice. Salary not less than £1,000 p.a. House and car available. Please write fully and in confidence to Box No. 530, I.Prod.E., 36, Portman Square, London, W.1.

Methods Engineer. Applications are invited by Markham & Co. Ltd. for the post of Methods Engineer. The Company is engaged in making medium to heavy machines, and in constructional steelwork, production being mainly of a special, non-repetitive nature. The Methods Engineer will be responsibility for studying and planning processes in machine, assembly, fitting or constructional shops and for jig and tool design. Applicants, age 35 or more, should have had similar experience in medium/heavy engineering. The successful candidate will be covered by a sound superannuation scheme. Applications, stating age, qualifications such as membership of a professional body, experience and present responsibilities and salary, will be treated in strict confidence, and should be addressed to The Secretary, Markham & Co. Ltd., Broad Oaks Works, Chesterfield.

Further Production Appointments appear overleaf.

THE INSTITUTION OF PRODUCTION ENGINEERS

CONFERENCE — HARROGATE — JUNE 25th–28th, 1953

To:- The Secretary, The Institution of Production Engineers, 36, Portman Square, London, W.1.

Date..................................

It is my intention to attend the Conference and *I shall be accompanied by my wife.

*I shall be accompanied by other guest(s)

I enclose remittance for Conference fee for myself	... ...	£1 10s. 0d.
*for my wife	... ...	10s. 0d.
..................Gentlemen guests @ £1 10s. 0d. each	... ...	£
..................Dinner tickets @ £1 5s. 0d. each	... ...	£
Total		£

Please send me a list of Harrogate Hotels.

Name (Block Letters)..

Grade of Membership..

Address (Block Letters)..

N.B. *Cheques should be made payable to 'The Institution of Production Engineers'.*

*Delete where inapplicable.

Engineer required with experience of processing, estimating, and ratefixing for precision aircraft components machined in small batches in modern factory located in new town 30 miles N.W. London. Only those with at least five years' experience of this type of work need apply, stating age, experience, qualifications and salary required. Housing accommodation can be provided for successful applicant. Mark replies "Engineer." Alford & Alder (Engineers) Ltd., Deacon Street, Walworth, S.E.17.

Production Methods Engineers required by light engineering firm in South East Lancs. Must be fully conversant with light and medium presses up to 100 tons, multi-stage progressive tools and strip forming machines, and must have sound machine shop experience on components applicable to light engineering trade. Apply stating age and full particulars of experience to Box No. 531, I.Prod.E., 36, Portman Square, London, W.1.

Assistant Machine Shop Superintendent for Machine Shop of large General Engineering works in London, engaged on maintenance and contract work. Must have served apprenticeship and have had subsequent experience on a variety of machine tools, and be capable of controlling shop and planning/progress/office when necessary. Age, experience and salary required to Box No. 532, I.Prod.E., 36, Portman Square, London, W.1.

Technical Controller required by Consulting Engineers office employing 30/40 staff. Successful applicant will be directly responsible to the Principal for the efficient technical functioning of the organisation, which is extensively engaged on Jig and Tool and special purpose machine design and detailing, and the preparation of planning layouts. Aircraft knowledge is also desirable but not essential. Applicants must also have knowledge of machining and handling methods. The Engineer appointed will represent the firm technically, which will entail a certain amount of travel and he must therefore have a pleasant personality both inside and outside the office. Salary will be in the range of £600/£850 per year, depending on qualifications and experience. Apply: The Principal, "Survey House," 18, Cardiff Road, Luton, Beds. Tel.: Luton 2553.

Planning and Estimating Engineer required for engineering department of light electro-mechanical manufacturers, S.E. London. Knowledge of transformer and electro-magnet design essential. H.N.C. preferred. Apply, giving full details and salary required, to Box No. 533, I.Prod.E., 36, Portman Square, London, W.1.

Time and Motion Study Engineer required for manufacturers of non-ferrous wire and strip. Applicants must be first-class men having a sound education and at least five years' experience of Time and Motion Study, and practical application of payment by results to both Production and Maintenance Service Departments. A knowledge of the non-ferrous metal trade, whilst not essential, will be an advantage. Pension scheme in existence. State age, experience and salary required. Box No. 534, I.Prod.E., 36, Portman Square, London, W.1.

Works Manager required by firm of precision engineers in Birmingham, engaged in specialised production. £1,200 to £1,400 p.a. is offered to a qualified engineer, preferably around 40 years of age, who must have a thorough grasp of works organisation, production and labour control. A pension fund is in being, and the position offers an interesting opportunity to a well-educated man able to carry through reorganisation in an old-established private company. Age and full details to Box No. 535, I.Prod.E., 36, Portman Square, London, W.1.

Young Assistant for Chief Estimator required for old-established firm in S.W. London. Must have sound engineering experience, preferably with knowledge of instrument making. Write in confidence, giving full particulars of general and technical education, past and present employment. State also age and salary required. Box. No. 536, I.Prod.E., 36, Portman Square, S.W.1.

EDUCATIONAL APPOINTMENTS
Hatfield Technical College
Lecturer in Production Engineering. Applicants are invited for the post of Lecturer in Production Engineering for H.N.C. and Final City and Guilds Machine Shop Engineering courses.

Assistant Lecturer, Grade B. Applications are also invited for the post of Assistant Lecturer, Grade B, in Mechanical and Production Engineering to teach engineering subjects to N.C. standard. Candidates should have an engineering degree or equivalent qualifications, such as Corporate Membership of the Institution of Mechanical Engineers or the Institution of Production Engineers, and have had good industrial experience. Salary scale: Lecturer, £940 x 25 – £1,040; Assistant Lecturer, Grade B, £490 x 25 – £765. Application forms (stamped addressed envelope) may be obtained from the Registrar, Roe Green, Hatfield, to whom they should be returned within 14 days of this advertisement.